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Indian Standard

TRANSFORMERS AND INDUCTORS FOR USE IN ELECTRONIC AND TELECOMMUNICATION EQUIPMENT — MEASURING METHODS AND TEST PROCEDURES

ICS 29.180; 29.100.10

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Price Group 15

Magnetic Components and Ferrite Materials Sectional Committee, LTD 13

NATIONAL FOREWORD

This Indian Standard which is identical with IEC 1007(1994) 'Transformers and inductors for use in electronic and telecommunication equipment — Measuring methods and test procedures' issued by International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Magnetic Components and Ferrite Materials Sectional Committee and approval of the Electronics and Telecommunication Division Council.

The text of the IEC has been approved as suitable for publication as Indian Standard without deviations. Certain conventions are however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

CROSS REFERENCES

In the adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 27 : Letter symbols to be used in electrical technology	IS 3722 : 1983 Letter symbols and signs used in electrical technology	Technically Equivalent
IEC 44-4(1980) Instrument transformers — Part 4 : Measurement of partial discharge	IS 11322:1985 Method for partial discharge measurement in instrument transformers	do
IEC 50 International Electrotechnical Vocabulary	IS 1885 Electrotechnical vocabulary	do
IEC 68-1 (1988) Environmental testing — Part 1 : General and guidance Amendment 1 (1992)	a) IS 9000 (Part 1):1988 Basic environmental testing procedures for electronic and electrical items: Part 1 General	do
	b) IS 9001 (Part 1) : 1984 Guidance for environmental testing: Part 1 General	do
IEC 68-2-1 (1990) Environmental testing — Part 2: Tests — Tests A: Cold Amendment 1(1993)	IS 9000 (Part 2) : 1977 Basic environmental testing procedures for electronic and electrical items: Part 2 Cold test	do
IEC 68-2-2 (1974) Environmental testing — Part 2: Tests — Test B: Dry heat Amendment 1(1993)	IS 9000 (Part 3) : 1988 Basic environmental testing procedures for electronic and electrical items: Part 3 Dry heat test	do
IEC 68-2-3 (1969) Environmental testing — Part 2: Tests — Test Ca: Damp heat, steady state	IS 9000 (Part 4) : 1988 Basic environmental testing procedures for electronic and electrical items: Part 4 Damp heat (steady state)	do

IEC 68-2-6 (1982) Environmental testing — Part 2 : Tests — Test Fc and guidance : Vibration (sinusoidal)	a) IS 9000 (Part 8):1988 Basic environmental testing procedures for electronic and electrical items: Part 8 Vibration (sinusoidal) test	Technically Equivalent
	b) IS 9001 (Part 13) : 1979 Guidance for environmental testing : Part 13 Vibration (sinusoidal) test	do
IEC 68-2-7 (1983) Environmental testing — Part 2 : Tests — Test Ga and guidance: Acceleration, steady state Amendment 1(1986)	a) IS 9000 (Part 9) : 1981 Basic environmental testing procedures for electronic and electrical items: Part 9 Acceleration (steady state) test	do
	b) IS 9001 (Part 15) : 1984 Guidance for environmental testing: Part 15 Acceleration (steady state) test	do
IEC 68-2-10 (1988) Environmental testing — Part 2 : Tests — Test J and guidance: Mould growth	IS 9000 (Part 10) : 1979 Basic environmental testing procedures for electronic and electrical items: Part 10 Mould growth test	do
IEC 68-2-13 (1983) Environmental testing — Part 2 : Tests — Test M: Low air pressure	IS 9000 (Part 13) : 1981 Basic environmental testing procedures for electronic and electrical items: Part 13 Low air pressure test	do
IEC 68-2-14 (1984) Environmental testing — Part 2 : Tests — Test N: Change of temperature Amendment 1 (1986)	IS 9000 (Part 14) : 1981 Basic environmental testing procedures for electronic and electrical items: Part 14 Test N: Change of temperature	do
IEC 68-2-17 (1978) Environmental testing — Part 2 : Tests — Test Q: Sealing Amendment 4 (1991)	IS 9000 (Part 15) : 1982 Basic environmental testing procedures for electronic and electrical items: Part 15 Sealing test	do
IEC 68-2-20 (1979) Environmental testing — Part 2 : Tests — Test T: Soldering Amendment 2 (1989)	IS 9000 (Part 18) : 1981 Basic environmental testing procedures for electronic and electrical items : Part 18 Solderabililty test	do
IEC 68-2-21 (1983) Environmental testing — Part 2 : Tests — Test U: Robustness of terminations and integral mounting devices Amendment 2 (1991) Amendment 3 (1992)	IS 9000 (Part 19) : 1981 Basic environmental testing procedures for electronic and electrical items: Part 19 Robustness of terminations and integral mounting devices	do
IEC 68-2-27 (1987) Environmental testing — Part 2 : Tests — Test Ea and guidance: Shock	a) IS 9000 (Part 7/Sec 1) : 1979 Basic environmental testing procedures for electronic and electrical items: Part 7 Impact test, Section 1 Shock	do
	b) IS 9001 (Part 17/Sec 1) : 1985 Guidance for environmental testing: Part 17 Impact test, Section 1 Shock test	do
IEC 68-2-29 (1987) Environmental testing — Part 2 : Tests — Test Eb and guidance: Bump	a) IS 9000 (Part 7/Sec 2) : 1979 Basic environmental testing procedures for electronic and electrical items: Part 7 Impact test, Section 2 Bump	do
	b) IS 9001 (Part 17/Sec 2) : 1985 Guidance for environmental testing: Part 17 Impact test, Section 2 Bump test	do

IEC 68-2-30 (1980) Environmental testing — Part 2 : Tests — Test Db and guidance : Damp heat, cyclic (12+12 - hour cycle) Amendment 1 (1985)	IS 9000 (Part 5/ Sec 2) : 1981 Basic environmental testing procedures for electronic and electrical items: Part 5 Damp heat (cyclic) test, Sec 2 12+12 h cycle	Technically Equivalent
IEC 68-2-42 (1982) Environmental testing — Part 2 : Tests — Test Kc: Sulphur dioxide test for contacts and connections	IS 9000 (Part 26):1980 Basic environmental testing procedures for electronic and electrical items: Part 26 Sulphur dioxide test for contacts and connections	do
IEC 68-2-45 (1980) Environmental testing — Part 2 : Tests — Test XA and guidance: Immersion in cleaning solvents	a) IS 9000 (Part 20) : 1979 Basic environmental testing procedures for electronic and electrical items : Part 20 Resistance to cleaning solvents and permanence of marking	do
	b) IS 9001 (Part 5) : 1979 Guidance for environmental testing : Part 5 Resistance to cleaning solvents and permanence of marking	do
IEC 68-2-52 (1984) Environmental testing — Part 2 : Tests — Test Kb: Salt mist, cyclic (sodium chloride solution)	IS 9000 (Part 11) : 1983 Basic environmental testing procedures for electronic and electrical items: Part 11 Salt mist test	do
IEC 270 (1981) Partial discharge measurements	IS 6209 : 1982 Methods for partial discharge measurement	do
IEC 367-1 (1982) Cores for inductors and transformers for telecommunications — Part 1 : Measuring methods Amendment 1 (1984) Amendment 2 (1992)	IS 7687 : 1980 Methods of measurement for cores for inductors and transformers for telecommunications	do
IEC 551(1987) Determination of transformer and reactor sound levels	IS 13964 : 1994 Methods of measurement of transformer and reactor sound levels	do
IEC 617 Graphical symbols for diagrams	IS 12032 : 1987 Graphical symbols for diagrams in the field of electrotechnology	Identical
IEC 651 (1979) Sound level meters Amendment 1 (1993)	IS 9779 :1981 Sound level meters	Technically Equivalent
ISO 3 :1973 Preferred numbers— Series of preferred numbers	IS 1076 (Part 1) : 1985 Preferred numbers: Part 1 Series of preferred numbers	Identical
ISO 497:1973 Guide to the choice of series of preferred numbers and of series containing more rounded values of preferred numbers	IS 1076 (Part 3) : 1985 Preferred numbers : Part 3 Guide to the choice of series of preferred numbers and of series containing more rounded values of preferred numbers	do
ISO 1000 : 1992 SI units and recommendations for the use of their multiples and of certain other units	IS 10005 : 1994 SI units and recommendations for use of their multiples and of certain other units	do

The concerned Technical Committee responsible for preparation of this standard has reviewed the provisions of the following International Publications and has decided that they are acceptable for use in conjunction with this standard:

IEC 68-2-58(1989)	Environmental testing—Part 2:Tests—Test Td: Solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)
IEC 695-2-2(1991)	Fire hazard testing — Part 2:Test methods — Section 2:Needle-flame test
IEC 695-2-4/0(1991)	Fire hazard testing — Part 2:Test methods — Section 4/Sheet 0:Diffusion type and pre-mixed type flame test methods
IEC 695-2-4/1(1991)	Fire hazard testing — Part 2:Test methods — Section 4/Sheet 1:1kW nominal pre-mixed test flame and guidance

Only the English language text of the International Standard has been retained while adopting it in this Indian Standard.

Indian Standard

TRANSFORMERS AND INDUCTORS FOR USE IN ELECTRONIC AND TELECOMMUNICATION EQUIPMENT — MEASURING METHODS AND TEST PROCEDURES

1 Scope

This standard describes measuring methods and test procedures for inductors and transformers for use in electronic and telecommunication equipment that may be involved in any specifications for such components, in particular those forming part of the IEC Quality Assessment System for Electronic Components (IECQ scheme).

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of IEC 1007. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on IEC 1007 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 27: *Letter symbols to be used in electrical technology*

IEC 44-4: 1980, *Instrument transformers – Part 4: Measurement of partial discharges*

IEC 50, *International Electrotechnical Vocabulary (IEV)*

IEC 68-1: 1988, *Environmental testing – Part 1: General and guidance*
Amendment 1 (1992)

IEC 68-2: *Environmental testing – Part 2: Tests*

IEC 68-2-1: 1990, *Environmental testing – Part 2: Tests – Tests A: Cold*
Amendment 1 (1993)

IEC 68-2-2: 1974, *Environmental testing – Part 2: Tests – Tests B: Dry heat*
Amendment 1 (1993)

IEC 68-2-3: 1969, *Environmental testing – Part 2: Tests – Test Ca: Damp heat, steady state*

IEC 68-2-6: 1982, *Environmental testing – Part 2: Tests – Test Fc and guidance: Vibration (sinusoidal)*

IEC 68-2-7: 1983, *Environmental testing – Part 2: Tests – Test Ga and guidance: Acceleration, steady state*
Amendment 1 (1986)

IEC 68-2-10: 1988, *Environmental testing – Part 2: Tests – Test J and guidance: Mould growth*

IEC 68-2-13: 1983, *Environmental testing – Part 2: Tests – Test M: Low air pressure*

IEC 68-2-14: 1984, *Environmental testing – Part 2: Tests – Test N: Change of temperature*
Amendment 1 (1986)

IEC 68-2-17: 1978, *Environmental testing – Part 2: Tests – Test Q: Sealing*
Amendment 4 (1991)

IEC 68-2-20: 1979, *Environmental testing – Part 2: Tests – Test T: Soldering*
Amendment 2 (1989)

IEC 68-2-21: 1983, *Environmental testing – Part 2: Tests – Test U: Robustness of terminations and integral mounting devices*
Amendment 2 (1991), Amendment 3 (1992)

IEC 68-2-27: 1987, *Environmental testing – Part 2: Tests – Test Ea and guidance: Shock*

IEC 68-2-29: 1987, *Environmental testing – Part 2: Tests – Test Eb and guidance: Bump*

IEC 68-2-30: 1980, *Environmental testing – Part 2: Tests – Test Db and guidance: Damp heat, cyclic (12 + 12-hour cycle)*
Amendment 1 (1985)

IEC 68-2-42: 1982, *Environmental testing – Part 2: Tests – Test Kc: Sulphur dioxide test for contacts and connections*

IEC 68-2-45: 1980, *Environmental testing – Part 2: Tests – Test XA and guidance: Immersion in cleaning solvents*

IEC 68-2-52: 1984, *Environmental testing – Part 2: Tests – Test Kb: Salt mist, cyclic (sodium chloride solution)*

IEC 68-2-58: 1989, *Environmental testing – Part 2: Tests – Test Td: Solderability, resistance to dissolution of metallization and to soldering heat of Surface Mounting Devices (SMD)*

IEC 270: 1981, *Partial discharge measurements*

IEC 367-1: 1982, *Cores for inductors and transformers for telecommunications – Part 1: Measuring methods*
Amendment 1 (1984), Amendment 2 (1992)

IEC 551: 1987, *Determination of transformer and reactor sound levels*

IEC 617, *Graphical symbols for diagrams*

IEC 651: 1979, *Sound level meters*
Amendment 1 (1993)

IEC 695-2: *Fire hazard testing – Part 2: Test methods*

IEC 695-2-2: 1991, *Fire hazard testing – Part 2: Test methods – Section 2: Needle-flame test*

IEC 695-2-4/0: 1991, *Fire hazard testing – Part 2: Test methods – Section 4/Sheet 0: Diffusion type and pre-mixed type flame test methods*

IEC 695-2-4/1: 1991, *Fire hazard testing – Part 2: Test methods – Section 4/Sheet 1: 1 kW nominal pre-mixed test flame and guidance*

ISO 3: 1973, *Preferred numbers – Series of preferred numbers*

ISO 497: 1973, *Guide to the choice of series of preferred numbers and of series containing more rounded values of preferred numbers*

ISO 1000: 1992, *SI units and recommendations for the use of their multiples and of certain other units*

3 Terminology

For the purpose of this standard the following definitions apply in addition to those of IEC 50:

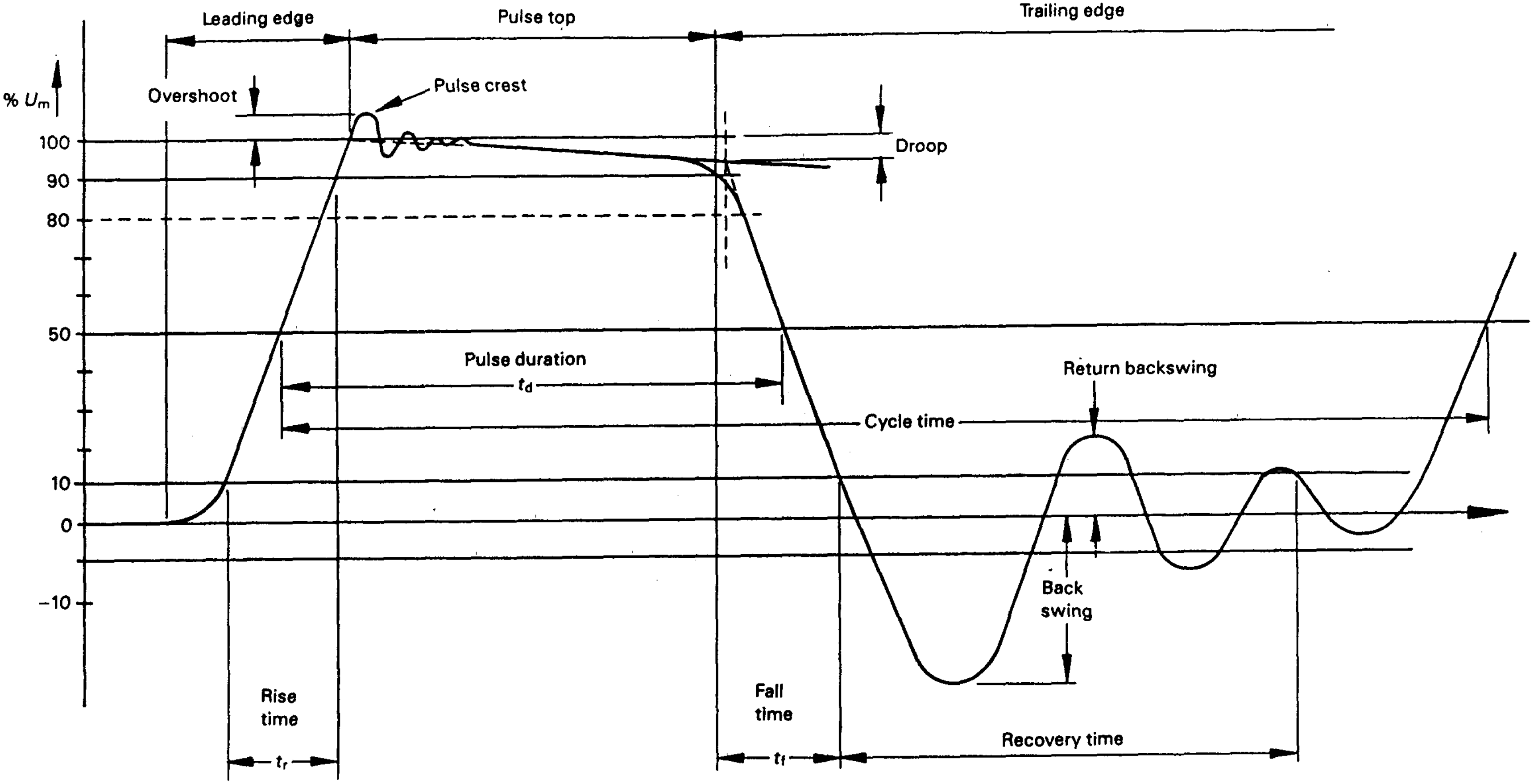
3.1 **component:** A transformer or an inductor.

3.2 **peak working voltage:** The maximum instantaneous voltage for which the winding insulation is rated under working circuit conditions.

3.3 **pulse waveform parameters** (see figure 1)

a) **peak pulse amplitude, U_m**: The maximum value of an extrapolated smooth curve through the top of the pulse, excluding any initial "spike" or "overshoot", the duration of which is less than 10 % of the pulse duration.

b) **pulse duration, t_d**: The time interval between the first and last instants at which the pulse amplitude equals 50 % of the peak pulse amplitude.



NOTE - For clarity in illustrating droop, the 80% and 10% points have been used in constructing the line which determines the border between the pulse top and the trailing edge.

Figure 1 - Pulse waveform parameters

c) **pulse rise time,** t_r: The interval between the first instant at which the pulse amplitude reaches 10 % of the peak pulse amplitude and the first instant at which the pulse amplitude reaches 90 % of the peak pulse amplitude, excluding any unwanted or irrelevant portion of the waveform.

d) **pulse fall time,** t_f: The interval between the last instant at which the pulse amplitude reaches 90 % of the peak pulse amplitude and the next instant at which the pulse amplitude reaches 10 % of the peak pulse amplitude, excluding any unwanted or irrelevant portion of the waveform.

NOTE – Where the value of the droop approaches 10 % of the peak pulse amplitude, the upper point defining fall time may be replaced by the last instant at which the pulse amplitude reaches 80 % of the peak pulse amplitude.

e) **droop:** The difference between the peak pulse amplitude and the amplitude of the extrapolated smooth curve through the top of the pulse, excluding any initial "spike" or "overshoot", at its intersection with the straight line through the points defining the pulse fall time, expressed as a percentage of the peak pulse amplitude.

f) **pulse crest:** The maximum amplitude of the pulse.

g) **overshoot:** The amount by which the pulse crest exceeds the peak pulse amplitude. Overshoot is expressed as a percentage of the peak pulse amplitude.

h) **backswing:** The maximum amplitude of the reverse pulse, i.e. the portion of the pulse after the zero-crossing, expressed as a percentage of the peak pulse amplitude.

i) **return backswing:** The maximum amplitude of the swing that follows the backswing, expressed as a percentage of the peak pulse amplitude.

j) **recovery time:** The time interval between the end of the pulse fall time and the time at which the pulse amplitude last reaches +10 % of the peak pulse amplitude. Exceptionally, a figure less than 10 % may be used, in which case the interval is termed "the X % recovery time".

k) **pulse repetition frequency (prf):** The average number of pulses in unit time when this is independent of the period over which it is measured.

3.4 **Q factor (quality factor):** The ratio of the energy stored to the energy dissipated during one cycle at a particular frequency in a specified winding. It is expressed in terms of either the series or the parallel components of reactance and loss resistance.

3.5 **harmonic distortion**: The square root of the sum of the square of all harmonic voltages up to and including the seventh harmonic (excluding the fundamental) expressed as a percentage or as a ratio in decibels of the fundamental.

3.6 **maximum winding temperature:** The mean temperature rise of any winding of the component under full load, when thermal stability has been achieved, added to the specified maximum ambient temperature.

3.7 **voltage-time product rating:** The voltage pulse amplitude multiplied by the time elapsed from the start of the pulse within which the non-linearity of the magnetizing current does not exceed a specified value.

3.8 **background (acoustic) noise:** The noise measured at a measuring point with the exclusion of that produced by the component under test.

3.9 **compass safe distance:** The distance from the pivot of the test magnetometer or compass to the nearest point on the surface of the component under test, at which the magnetic deviation is limited to a stated value.

3.10 **duty ratio; duty factor:** The ratio of pulse duration t_d to the cycle time.

3.11 **current transformer parameters**

a) **burden:** That property of the circuit connected to the secondary winding of a current transformer which determines the real and reactive power at the secondary terminals. It is expressed as total impedance with effective resistive and reactive components or as the total volt-amperes and power factor at the specified values of current and frequency.

b) **current transformation ratio, *k*:** The ratio of the r.m.s. value of the primary current to the r.m.s. value of the secondary current under specified conditions.

c) **phase angle:** The angular displacement between the vectors representing the primary and secondary currents of the transformer. The phase angle is positive when the secondary current leads the primary current.

d) **ratio error:** The difference between the measured current transformation ratio k and its nominal value k_n, divided by the measured value, and expressed as a percentage.

$$\text{ratio error} = \frac{k_n - k}{k} \times 100 \text{ (per cent)}$$

3.12 **electrostatic screen:** A conducting screen inserted between windings that, when it is connected to earth, considerably reduces the transference of unwanted signals from one winding to the other via interwinding capacitance.

3.13 **safety screen:** A conducting screen inserted between windings that, when it is connected to earth, effectively prevents fault currents flowing between those windings, in the event of an insulation failure.

3.14 **polarity (applicable to single-phase windings):** A property of a single-phase winding such that a terminal on one winding has the same polarity as a terminal on another winding if, when the other ends of the windings are connected to form a common terminal and the transformer/inductor is energized with a sinusoidal voltage, the induced voltage appearing between each of the two terminals and the common terminal is rising positively through zero at the same instant of time.

3.15 **uniformly-insulated winding:** A winding in which the insulation to earth is, at all points, designed to withstand an electric strength test of a value appropriate to the insulation of the high-voltage end.

3.16 **graded-insulated winding:** A winding in which insulation to earth is graded from the amount at the high-voltage end to a smaller amount at the low-voltage end.

NOTE – Such a winding should withstand an electric strength test of a value appropriate to the insulation of the low-voltage end.

4 Test procedures

4.1 *Test and measurement conditions*

Unless otherwise specified all tests shall be carried out under standard atmospheric conditions for testing as specified in IEC 68-1. Where there is a requirement for components to attain temperature stability this shall be in accordance with 4.8 of IEC 68-1.

Unless otherwise stated in the detail specification, all voltages and currents shall be sinusoidal; values shall be taken as r.m.s. and polyphase supplies shall be assumed to be balanced.

The "information to be stated" that is required to complete the descriptions of test methods in this clause shall be specified in the relevant detail specification for the component. The detail specification shall also specify the test fixture to be used in association with a component, where this is intended for use at frequencies high enough for the length of test leads to become significant.

4.1.1 *Measurement uncertainty*

The limits quoted in detail specifications shall be absolute. The tolerance values applying to the actual measurement system shall be taken into account when the measurements are assessed against specification limits. Where tolerances in respect of set conditions or instrument error have been prescribed these shall be regarded as additional minimum requirements.

4.1.2 *Alternative test methods*

The test and measurement methods given in the relevant specification shall not be regarded as the only methods to be used. Special test equipment and automatic test sets are available, which may also be used. However, the tester shall satisfy the customer or relevant authority (see Note 1) that any alternative methods which he may use will give results equivalent (see Note 2) to those obtained by standard methods. In the case of dispute, for referee and reference purposes the specified methods only shall be used. Alternative test methods shall not be shown in detail specifications.

NOTES

1 Such as a National Supervising Inspectorate within the IECQ scheme.

2 By "equivalent" it is meant that the value of the characteristic established by such other method and deemed acceptable in accordance with the limits ascribed to such other method will fall within the specified limits when measured by the specified method.

4.2 *Visual inspection*

Visual inspection shall be performed under normal factory lighting without visual aids. The condition, workmanship, marking and finish shall be satisfactory.

NOTE – If special lighting and/or visual aids are necessary for the acceptance of particular components (e.g. very small components), these may be specified as additional tests in the relevant detail specification.

4.2.1 *Safety screen position*

NOTE – Sometimes the term "isolating screen" is used as an alternative to "safety screen".

Purpose: To determine the position of a safety screen in relation to adjacent windings.

Procedure: The fitted and positioned safety screen shall be inspected before being obscured by subsequent windings. The safety screen shall:

a) totally cover the winding around which it is wrapped such that the "finish" end overlaps the "start" end by no less than the amount specified in the detail specification;

b) be adequately insulated so as not to comprise a short-circuited winding;

c) have edges extending sufficiently along the winding being screened to prevent direct contact between windings.

NOTE – Screens fitted to toroidal transformers may consist of a number of turns of conductive strip provided that each turn overlaps the adjacent turn by not less than 5 % of the strip width.

Information to be stated:

- minimum overlap.

4.2.2 *Quality of solder joints*

NOTE – A good solder joint is one that has excellent electrical contact between the parts joined and good mechanical strength. Examples of good solder joints are shown in figure 2. Figure 3 illustrates defective joints.

Purpose: To determine the quality of all solder joints.

Procedure: All solder joints shall be inspected to ensure that the following requirements are complied with:

Requirements: Soldered joints shall:

a) exhibit good tinning as evidenced by the free flowing of solder with wetting of the termination;

b) be smooth with no spikes;

c) be bright and shiny;

d) be without rough patches;

e) shall have a concave surface and the outline of the wire shall be visible under the surface of the solder;

f) not have been moved during soldering (such joints exhibit an "orange peel" effect, as shown in figure 3a);

g) not be "dry" (that is, shall not exhibit a distinct line where the solder fillet joins the wire or have a high contact angle between the solder and the wire (see figure 3b));

h) be wired at terminals in such a way as to leave no residual stress (see figure 3c);

i) not exhibit "wicking" (that is, the joining wire shall not be overheated, leading to the movement of solder into multi-stranded wires (see figure 3d)).

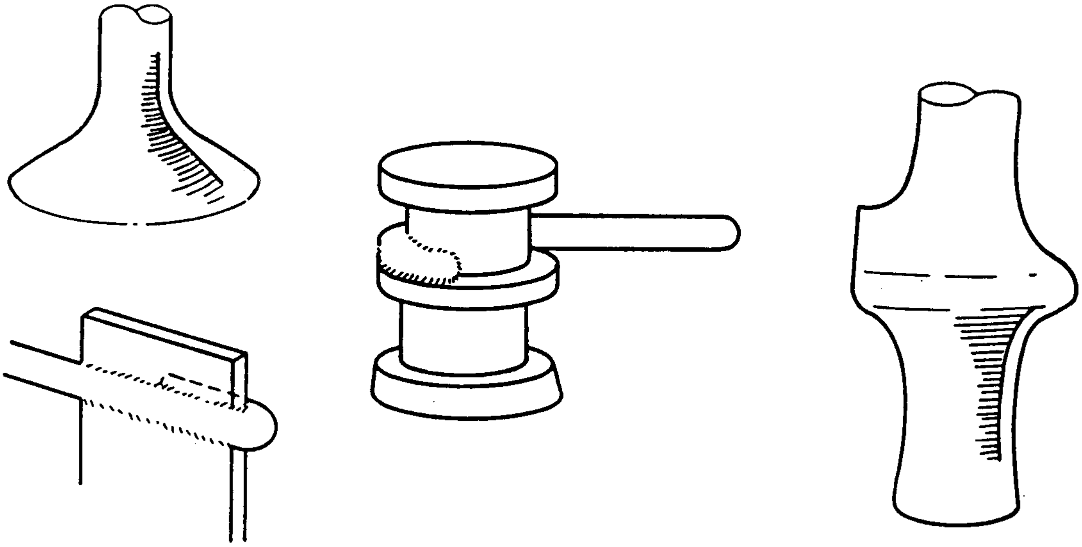


Figure 2 – Examples of good solder joints

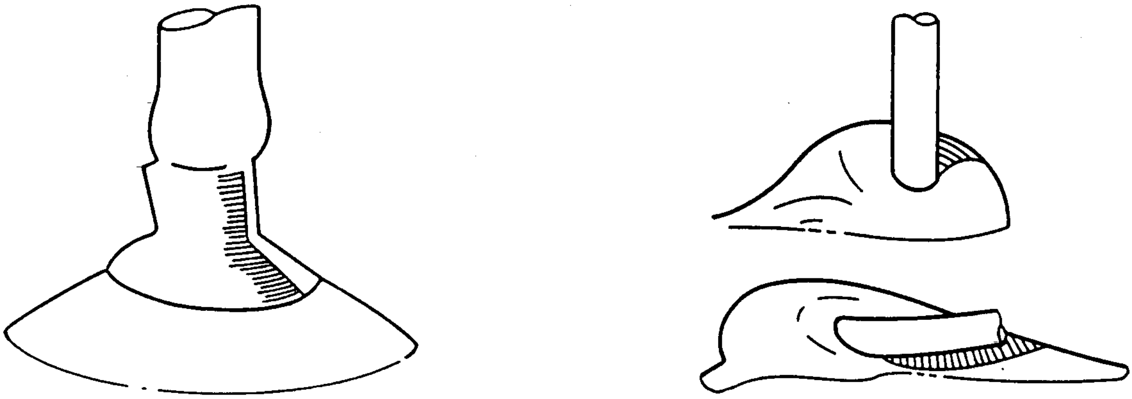


Figure 3a - Moved joint

Figure 3b - Dry joints

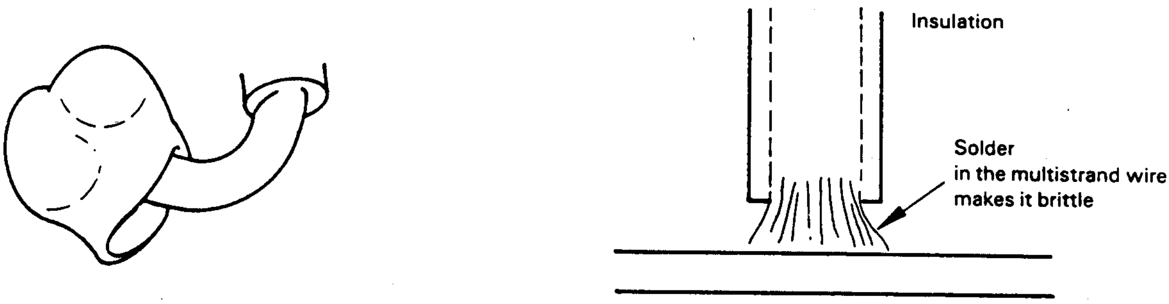


Figure 3c - Mechanically stressed joint

Figure 3d - Wicking

Figure 3 – Examples of defective joints

4.3 *Dimensioning and gauging procedure*

The dimensions shall be verified as being in accordance with the relevant specification.

4.4 *Electrical test procedures*

4.4.1 *Winding resistance*

4.4.1.1 *D.C. winding resistance*

Purpose: To determine the d.c. resistance of a winding or windings between specified terminations.

Procedure: The resistance shall be measured by a suitable method.

Where required by the detail specification, the ambient temperature θ (in °C) shall be measured and the result of the resistance measurement R_m (in Ω) corrected to the corresponding value at 20 °C, R_{20} (in Ω) by means of the following formula:

$$R_{20} = \frac{k + 20}{k + \theta} R_m$$

where k is a constant related to the thermal coefficient of resistivity. For the purposes of this standard, the value for copper shall be taken as 234,5 and for aluminium as 228,1.

NOTE – For safety reasons, consideration should be given to short-circuiting windings capable of producing high voltages at current interruption.

Information to be stated:

a) terminations between which the measurement is to be made;

b) whether the result of measurement should be corrected to 20 °C, and if so, the value of k to be used for materials other than copper or aluminium.

NOTES

1 The selected method should be determined by the ease of operating the test and the accuracy required. The accuracy of the equipment should be at least ten times better than the accuracy required of the test.

2 The measuring current should not be so large as to cause self-heating or to have a significant magnetizing effect on the component.

4.4.1.2 *Continuity*

Purpose: To verify the continuity of a specified winding.

Procedure: Continuity shall be established using a suitable d.c. or a.c. voltage or current source, and a suitable detector.

Information to be stated:

- winding to be tested.

NOTES

1 The current should not be so large as to have a significant magnetizing effect on the component.

2 Care should be taken in testing a winding with a high inductance value as a high voltage may be generated.

3 Where there are parallel paths, as with multiple windings or in polyphase components, a d.c. resistance check may be necessary to ensure that the path under examination is not being influenced by shunt paths.

4.4.2 *Insulation tests*

4.4.2.1 *Electric strength test*

Purpose: To ensure that the insulation of uniformly-insulated windings and the low-voltage end insulation of graded-insulated windings are adequate.

NOTES

1 This test is not suitable for the high-voltage end insulation of windings having graded insulation or designed to have one point earthed*. The high-voltage end insulation of such windings can be tested only by the application of an appropriate induced voltage test (see item b) of **special conditions of test** of 4.4.2.2).

2 In certain cases it may be appropriate to demonstrate the adequacy of the low-voltage end insulation of graded-insulated windings during the induced voltage test (see item b) of **special conditions of test** of 4.4.2.2).

Procedure: A test voltage whose value is selected from the table below, unless otherwise specified, shall be applied between specified pairs of isolated elements of the component. All windings shall be short-circuited. Windings and screens on one side of the insulation system shall be connected to frame, core and earth while windings and screens on the other side shall be connected together.

Electric strength test voltages

Peak working voltage V_{pk}	A.C. test voltage, 45 - 65 Hz (r.m.s.) $V_{r.m.s.}$	D.C. test voltage V
<25	50	71
>25 to 50	100	141
>50 to 100	300	424
>100 to 175	500	707
>175 to 700	2,8 x peak working voltage	4 x peak working voltage
>700	1,4 x peak working voltage + 1 000	2 x peak working voltage + 1 400

The test voltage shall be increased at a convenient rate but not exceeding 2 kV per second, from zero to the specified value, maintained at this value for the specified time (unless breakdown occurs), then decreased to zero at the same rate.

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* In the USA, "ground" is used in place of "earth" and "grounded" in place of "earthed".

For fluid-filled components, except for those designed for operation in one plane only and so marked, approximately half the test sample shall be tested with terminals uppermost and half with the terminals underneath.

If a specified environmental conditioning is required for this test the component shall be held for a minimum of 6 h unless otherwise specified in the specified conditions. (See IEC 68 for information on environmental testing.)

There shall be no evidence of heating, breakdown or deterioration. Ionization shall not be regarded as a criterion of breakdown. The leakage current shall not exceed the specified value.

Information to be stated:

a) terminations between which the test is to be made;

b) test voltage (for a winding having graded-insulation, values shall be given for both ends of the winding);

c) frequency of a.c. test voltage (if different from the values shown in the table);

d) test duration;

e) maximum leakage current, if specified.

NOTES

3 If breakdown occurs during the test it can at first be detected by sporadic and intermittent increases in leakage current followed by a significant increase to a constant higher value which, on many electric strength test sets, is accompanied by a partial or complete collapse of the voltage. This type of breakdown may be caused by partial breakdown in ionized voids and weakened insulation which then avalanches to complete breakdown in the form of arc-over or arc-through.

4 Electric strength test voltages may be hazardous. Extreme care should be taken in performing this test.

4.4.2.2 *Induced voltage test*

Purpose: To verify the adequacy of inter-turn and inter-layer insulation of transformers and inductors, and to verify the adequacy of the high-voltage end insulation of windings having graded-insulation.

Special conditions of test

The following special conditions apply:

a) Uniformly insulated windings are normally tested as in **Procedure** 1, 2 or 3, as appropriate. Any point of a winding may be earthed during the test as specified.

b) Windings having graded-insulation are normally tested as in **Procedure** 1, 2 or 3, as appropriate. A point on such a winding may be earthed or raised to a specified voltage above earth during the test. The induced voltage shall be such that, when added vectorially to any applied voltage, the high-voltage end of the winding is raised to the appropriate peak test voltage given in 4.4.2.1, **Procedure.**

If the specified voltage above earth is alternating, then it shall be of the same frequency as the induced voltage.

NOTE 1 – In general, during the execution of the induced voltage test, no winding should be permitted to "float", i.e. to remain unconnected at both ends.

Procedure 1: Applicable to transformers and inductors intended for energizing by sinusoidal waveforms.

A specified test voltage of not less than twice the rated supply voltage at a frequency of not less than twice the lowest rated frequency shall be applied across the specified winding. The duration and manner of application shall be as specified in the detail specification.

Procedure 2: Applicable to transformers and inductors intended for energizing by pulse waveforms.

Specified test voltage pulses of amplitude not less than twice the rated pulse amplitude, at a specified pulse repetition frequency of not less than 25 % of the maximum rated pulse repetition frequency and with a specified pulse duration not less than 25 % of the rated maximum pulse duration and normally[*] not greater than 50 % of the rated pulse duration shall be applied across the winding. The duration and manner of application shall be as specified in the detail specification.

Procedure 3: Applicable to transformers and inductors intended for energizing by non-sinusoidal periodic waveforms such as those in power supplies operating with semiconductors in a switched mode.

A specified sinusoidal test voltage of peak value not less than twice the maximum rated peak value for the input voltage waveform and at a specified frequency, derived as follows, shall be applied across the specified winding. The duration and manner of application shall be as specified in the detail specification.

The test frequency shall be such that its cyclic period is normally[**] not greater than the effective shortest half-cycle period of the operative waveform for which the component is intended e.g. in the case of pulse width modulated symmetrical or asymmetrical waveforms the effective half-cycle shall be taken to be the effective minimum on-time of the electronic switch.

Duration for application of test voltage in Procedures 1, 2 and 3

The duration of application of the test voltage shall be specified as one of the following:

a) The applied voltage shall be raised from one-third of the specified voltage to the full

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Pulse durations greater than 50 % of the rated maximum value may be specified provided that core flux saturation or other abnormalities are shown not to be incurred thereby.

[**] A lower test frequency may be specified provided that core flux saturation or other abnormalities are shown not to be incurred thereby.

value which shall then be maintained for 60 s ± 5 s before reducing the voltage to one-third of its value and hence to zero.

b) 5 s to 10 s (value to be stated).

Requirements:

There shall be no evidence of heating, breakdown or deterioration. Ionization shall not be regarded as a criterion of breakdown.

Information to be stated in the detail specification:

a) the test voltage (r.m.s. or peak as applicable);

b) the winding(s) to be energized (see note 2);

c) the winding point intended to be connected to a known potential and the value of this potential (if applicable);

d) the duration of application of test voltage;

e) the test frequency or pulse repetition frequency (as applicable);

f) the pulse duration (applicable to Procedure 2).

NOTE 2 - A source of test voltage may be connected to windings other than the normal input winding in order to obtain the necessary voltages.

4.4.2.3 *Insulation resistance*

Purpose: To measure the resistance of the insulation between the various parts of the component.

Procedure: Unless otherwise specified the insulation resistance shall be measured with a d.c. voltage of either:

100 V ± 15 V for windings with peak working voltage < 500 V, or

500 V ± 50 V for windings with peak working voltage ≥ 500 V.

The test voltage shall be applied until a steady reading is obtained or, failing that, for 60 s ± 5 s.

If a specified environmental conditioning is required the component shall be held in the specified condition for a minimum of 6 h, unless otherwise specified. (See IEC 68 for information on environmental testing.)

Information to be stated:

a) terminations between which the measurement is to be made;

b) peak working voltage of each winding;

c) environmental conditioning.

4.4.3 *Losses*

4.4.3.1 *No-load current*

Purpose: To verify that the core is of the required quality and is correctly assembled and that there are no short-circuited parts of the windings.

Procedure: The specified voltage at the frequency or frequencies specified shall be applied from a low impedance source to the input winding with all other windings open-circuit. The harmonic distortion of the applied voltage shall be less than 6 %. The input current shall be measured with a true r.m.s. instrument, whose impedance is sufficiently low not to affect the applied voltage by more than 1 %. The input current shall be measured when its value is stabilized. For polyphase components all input currents shall be measured.

Information to be stated:

a) a.c. voltage;
b) test frequency;
c) winding to be tested;
d) maximum r.m.s. value of input current.

4.4.3.2 *No-load loss*

Purpose: To verify that the transformer is of the required quality and is correctly assembled and that there are no short-circuited parts of the windings.

Procedure: The specified voltage at the specified frequency shall be applied to the input winding via a suitable wattmeter, all other windings being open-circuit. The harmonic distortion of the voltage when applied to the winding shall be less than 6 %.

The power loss shall be measured when its value has been stabilized, a correction being made for the wattmeter losses if these are significant.

Information to be stated:

a) test voltage;
b) test frequency;
c) winding to be connected;
d) maximum power loss.

4.4.3.3 *Quality factor, Q*

Purpose: To determine the quality factor of a component at a particular frequency.

Procedure: The quality factor, Q, shall be measured at the specified voltage and frequency using a suitable method, for example:

a) a suitable inductance bridge;

b) circuit magnification meter (Q-meter);
c) insertion loss measurement (see, for example, appendix H of IEC 367-1);
d) damped oscillation method (see, for example, appendix G of IEC 367-1).

The references given for methods c) and d) above contain the appropriate formulae and calculations.

The relationships between the effective inductance L and resistance R of a component under test, according to whether a series (s) or parallel (p) circuit representation is used, and the measured value of Q at the frequency f are given by:

$$Q = \frac{2\pi f L_s}{R_s}$$

and

$$Q = \frac{R_p}{2\pi f L_p}$$

respectively.

Information to be stated:

a) winding connections;
b) a.c. voltage;
c) measuring frequency;
d) limits of Q value.

NOTE – In tests of high Q components, corrections for capacitor losses and terminating impedance may be necessary.

4.4.4 *Inductance*

4.4.4.1 *Effective inductance and effective resistance*

Purpose: To measure the effective inductance and, if specified, the effective resistance of a winding.

Procedure: The inductance and, if specified, the effective resistance of the specified winding shall be measured on a suitable bridge at the specified voltage and frequency with polarizing d.c. applied if required.

Information to be stated:

a) winding to be measured;
b) form of measurement (see note);
c) a.c. voltage on the measured winding;
d) measuring frequency;
e) polarizing d.c.

NOTES

1 In the case of low Q components, typically 10 or less, it is necessary to specify series or parallel mode of measurement.

2 There is a difference between the true inductance L_0 measured at low frequencies, and the effective inductance L_e measured at a frequency approaching self-resonance.

4.4.4.2 *Leakage inductance, L_l*

Purpose: To determine the leakage inductance between windings of a transformer.

Procedure: The series inductance of the specified winding shall be measured on a suitable bridge, the remaining windings or a specific winding being short-circuited as specified.

Information to be stated:

a) winding connections;

b) a.c. voltage;

c) measuring frequency (see note 2).

NOTES

1 In performing this test the applied voltage should be sufficiently low for the currents in the short-circuited windings not to exceed their rated values.

2 The selected frequency should ensure that the indicated value of the series inductance falls on the straight minimum portion of the graph of measured inductance versus frequency (see figure 4).

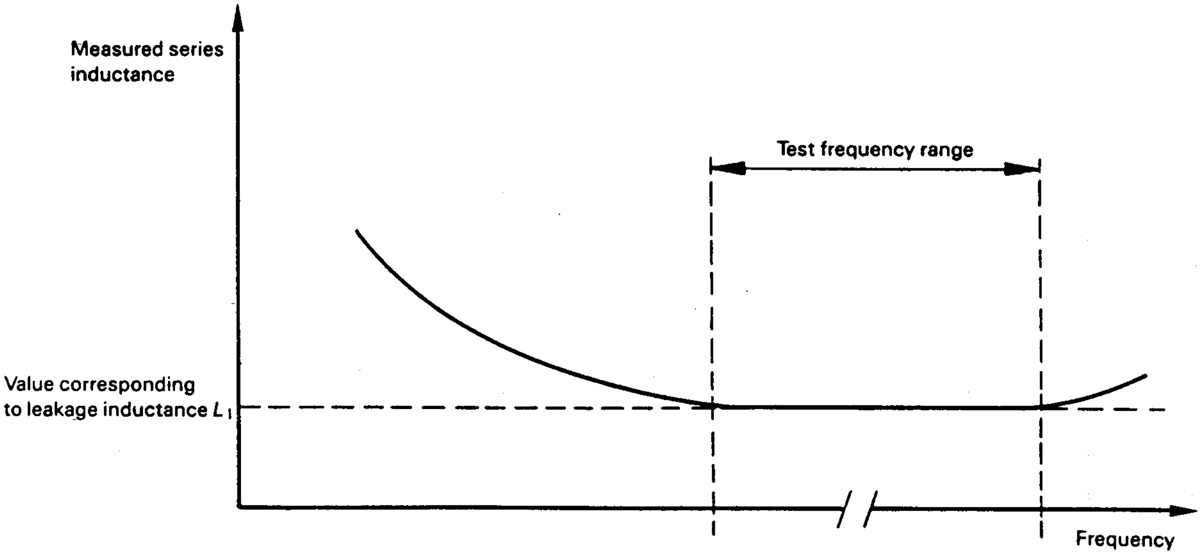


Figure 4 – Variation of measured series inductance with frequency

4.4.5 *Unbalance*

NOTE – The following tests are concerned with the various types of unbalance in transformers.

4.4.5.1 *Capacitance unbalance*

Purpose: To determine the capacitance unbalance between specified terminations of a transformer.

Procedure: A suitable circuit for the measurement of this parameter is shown in figure 5. The test frequency shall be high enough to make the effect of inductance unbalance negligible.

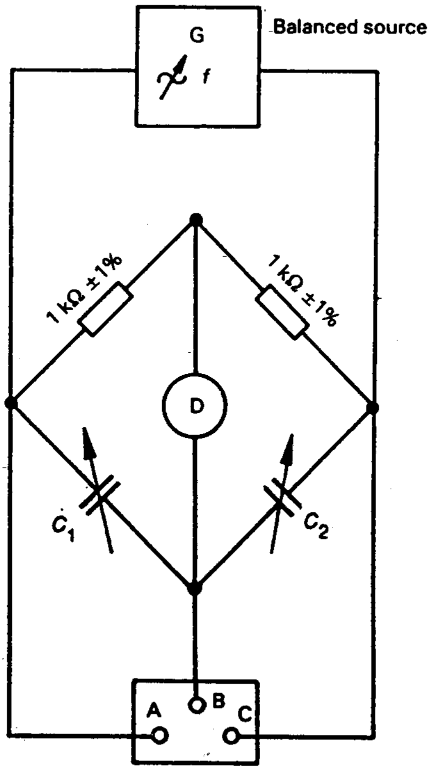
With no connections to the transformer under test, capacitor C_1 is set to a specified value (for example 50 pF) and a balance is obtained by varying C_2. The transformer is then connected as shown and the bridge is rebalanced by varying C_1. The difference between the two values of C_1 is the capacitance unbalance.

Information to be stated:

a) initial value of C_1;

b) component connections;

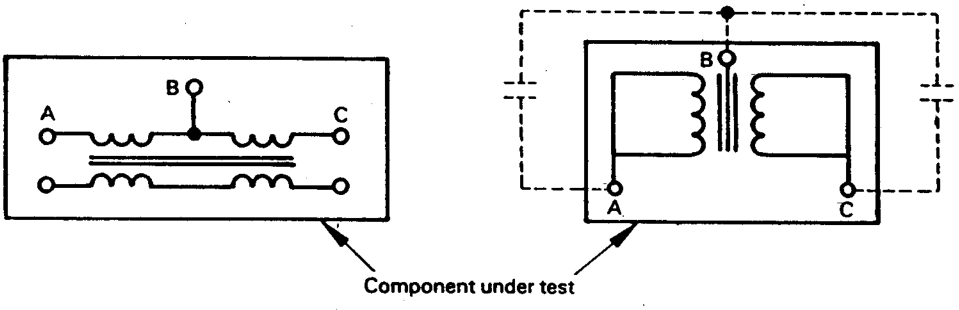
c) frequency.



D is a high-impedance detector

The 1 kΩ ratio arms are non-reactive resistors

C_1 and C_2 are calibrated variable capacitors of the same type, preferably air dielectric



NOTE – Terminal letters are for reference only.

Figure 5 – Circuit for measuring capacitance unbalance

4.4.5.2 *Common mode rejection ratio*

Purpose: To determine the degree of rejection of the common mode input voltage.

Procedure: A suitable circuit for this test is shown in figure 6.

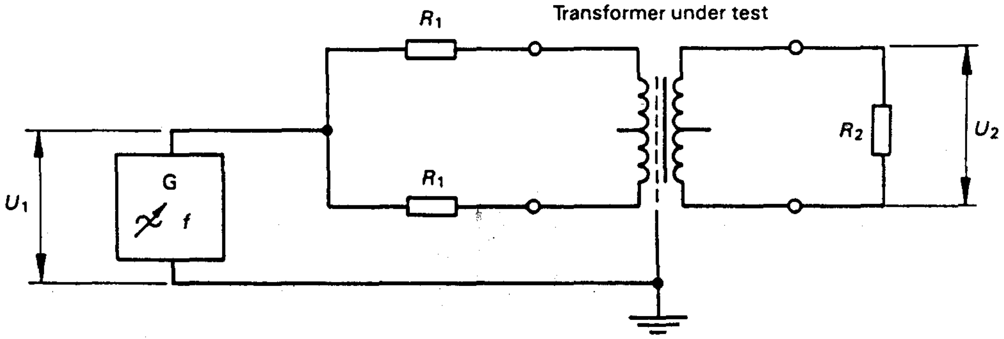


Figure 6 – Circuit for determining common mode rejection ratio

The input terminals of the transformer under test are connected to the high potential terminal of a voltage source through equal resistors R_1, each equal to half the input impedance. The output terminals of the transformer under test are connected to a resistor R_2 whose value is specified in the detail specification.

The common mode rejection ratio (CMRR) in decibels is given by:

$$\mathrm{CMRR} = -20 \log (U_2/U_1)$$

where

U_1 is the voltage of the common mode source, and

U_2 is the voltage of the common mode signal emerging from the component under test.

Information to be stated:

a) transformer connections, including earth connections;
b) test frequency;
c) input impedance, $2R_1$;
d) load resistor R_2.

4.4.5.3 *Impedance unbalance*

Purpose: To determine the impedance unbalance between two windings of a transformer, intended to be equal.

Procedure: A suitable circuit for this test is shown in figure 7.

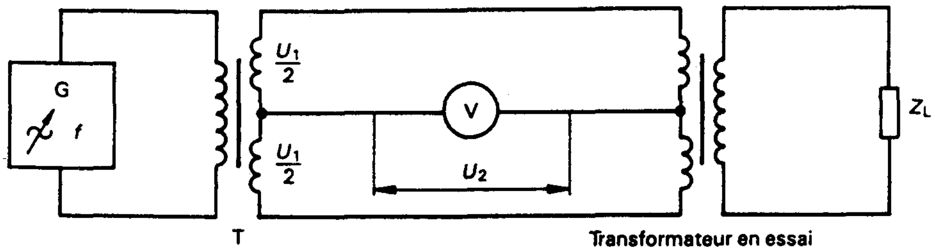


Figure 7 – Circuit for measuring impedance unbalance

A precision screened and balanced transformer shall be used as the input transformer T and its symmetry shall be at least 20 dB better than the expected reading for the transformer under test.

If the voltage caused by unbalance, as measured by the voltmeter V, is U_2, then the impedance unbalance a_{uz} in decibels is given by the expression:

$$a_{uz} = 20 \log (U_1/2U_2)$$

Information to be stated:

a) component connections;
b) input voltage U_1;
c) load impedance Z_L;
d) test frequency.

NOTE – It is recommended that V is a frequency selective voltmeter, tuned to the test frequency.

4.4.5.4 *Crosstalk attenuation*

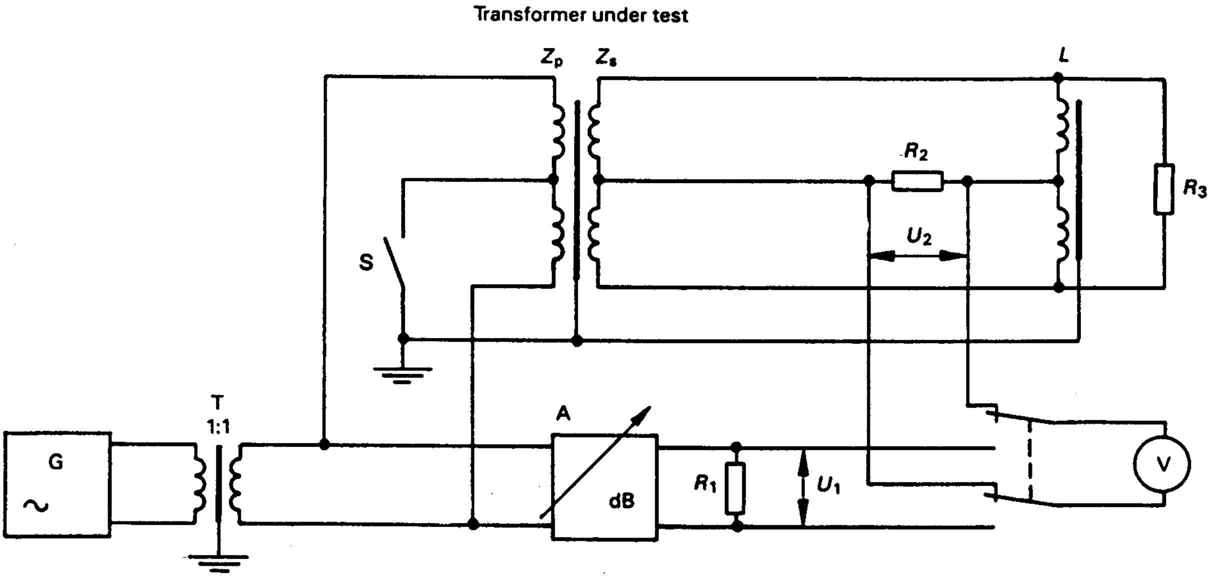
Purpose: To determine the crosstalk attenuation of a telecommunication line transformer which is for use in a phantom circuit.

Procedure: A suitable test circuit is shown in figure 8.

The attenuator shall be adjusted until $U_1 = U_2$.

The crosstalk attenuation a_c in decibels shall then be calculated in terms of the attenuator setting a_r from the following expression:

$$a_c = a_r + 10 \log 2 - 10 \log (Z_p/Z_s)$$



T	is a precision screened and balanced transformer.
L	is a precision screened and balanced centre-tapped inductor, whose symmetry is at least 20 dB better than that expected for the transformer under test.
G	is a generator of low-output impedance.
A	is a precision variable attenuator of characteristic impedance R_1.
V	is a voltmeter suitable for the operating frequency of the test set and having an impedance greater than 10 kΩ.
S	is a switch enabling transformer primary centre tap to be earthed, if required.
Z_p	is the specified primary impedance.
Z_s	is the specified secondary impedance.
R_1	is a resistor of value equal to the characteristic impedance of the attenuator.
R_2	is a resistor of value equal to the phantom circuit impedance.
R_3	is a resistor of value equal to the specified secondary impedance.

Figure 8 – Circuit for determining crosstalk attenuation

Information to be stated:

a) transformer primary and secondary impedances;
b) phantom circuit impedance;
c) test frequency if other than 800 Hz;
d) transformer primary winding centre tap to be earthed or not earthed.

4.4.5.5 *Voltage unbalance*

Purpose: To determine the voltage unbalance between two windings intended to be equal.

Procedure: The transformer shall be connected to a source of specified voltage and frequency. A resistive load simulating the operating conditions shall be connected to the appropriate windings; the voltages across the windings under test shall be measured and the voltage unbalance determined from the measured values U_1 and U_2 as a percentage, using the formula:

$$\frac{U_1 - U_2}{U_1} \times 100$$

or expressed in decibels by the parameter a_{uv} given by the expression:

$$a_{uv} = 20 \log U_1/(U_1 - U_2)$$

where U_1 is the larger of the measured values.

Information to be stated:

a) test frequency;
b) voltage to be applied;
c) component connections;
d) load resistance.

4.4.5.6 *Resistance unbalance*

Purpose: To determine the d.c. resistance unbalance between two windings intended to be equal.

Procedure: The d.c. resistance of each specified winding shall be measured using an instrument having a resolution of 0,1 times the ohmic value of the specified d.c. resistance unbalance, or better. The measuring current shall be chosen so as not to cause heating or significant magnetization of the component under test.

The resistance unbalance shall be calculated as a percentage from the formula:

$$\frac{R_1 - R_2}{R_1} \times 100$$

or expressed in decibels by the parameter a_{ur} given by the expression:

$$a_{ur} = 20 \log R_1/(R_1 - R_2)$$

where R_1 is the larger of the measured values and R_2 the smaller.

Information to be stated:

- winding connections.

4.4.6 *Capacitance*

4.4.6.1 *Self-capacitance (distributed capacitance)*

Purpose: To determine the effective self-capacitance (distributed capacitance) of specified windings.

Procedure 1: Measurement shall be made with short leads connecting the terminations to a Q-meter. At the specified frequency (at least five times the self-resonant frequency of the winding) the winding shall be resonated with a specified inductor. The winding shall be removed from the Q-meter and, by adding capacitance in place of the winding, the inductor shall be resonated again at the same frequency. The added capacitance shall be taken as the effective self-capacitance of the winding.

Procedure 2: Capacitors of known values shall be connected in parallel with the winding, and the resonant frequencies of the parallel circuits so formed shall be measured on a suitable parallel impedance or admittance bridge. The capacitance values shall be plotted against $1/f^2$. If this yields a straight line, the intercept on the capacitance axis shall be taken as numerically equal to the required capacitance. A typical plot is shown in figure 9.

A non-linear plot indicates eddy current shielding in which case the capacitance values shall then be plotted against:

$$1 / f^2 (L_1/L)$$

where

L is the inductance of the winding at low frequency;

L_1 is its inductance at the frequency of measurement, the change in value occurring because of eddy current shielding.

For both Procedures 1 and 2 the earthing conditions shall be as specified.

NOTE – In practice, Procedure 2 is of doubtful accuracy since the intercept is very sensitive to the slope of the "straight line", and the points tend to exhibit scatter and lie too far from the origin.

Information to be stated:

a) winding connections;

b) Procedure 1 or 2;

c) for Procedure 1, the measuring frequency;

d) for Procedure 1 only, a description of the specified inductor;

e) earthing conditions.

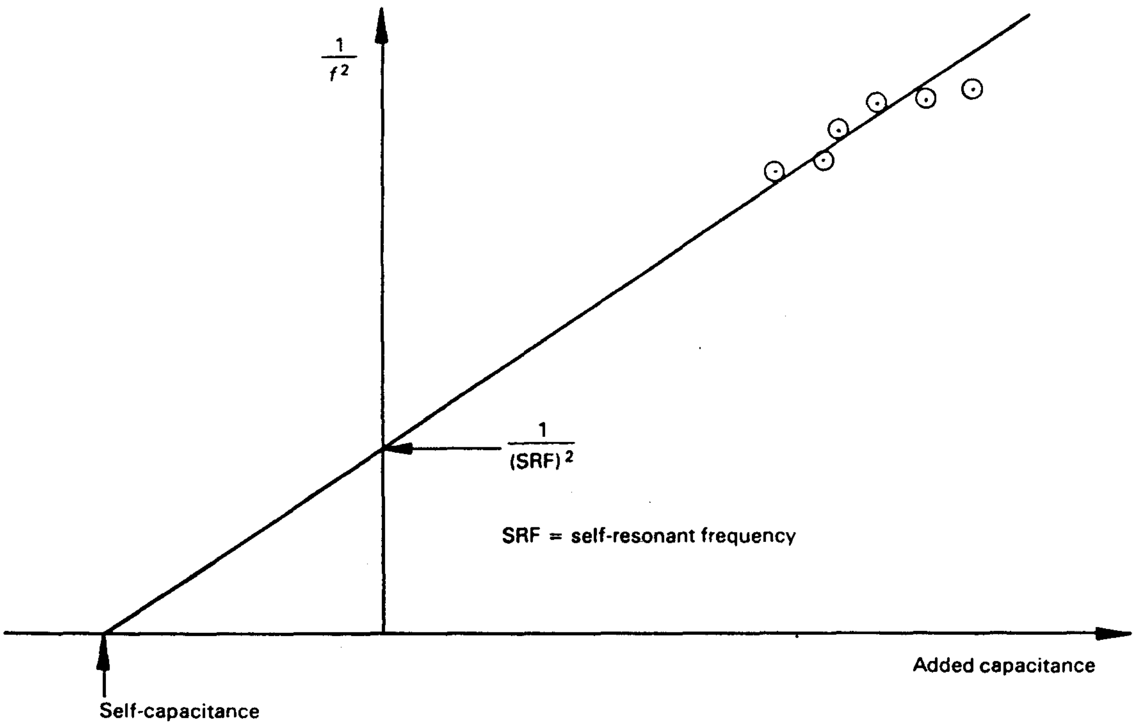


Figure 9 – Typical graph for determining self-capacitance

4.4.6.2 *Interwinding capacitance*

Purpose: To determine the effective capacitance between specified windings.

Procedure 1: Windings to be included in the measurement shall be short-circuited, unless otherwise specified in the detail specification. The specified points of connection, between which the effective capacitance is required, shall be connected to a suitable capacitance bridge.

NOTE – This method is suitable for use at relatively low frequencies.

Procedure 2: The specified points of connection of the windings to be tested, each short-circuited unless otherwise required, shall be connected as shown in a test circuit such as that of figure 10, where X_c represents the reactance of the capacitance to be measured.

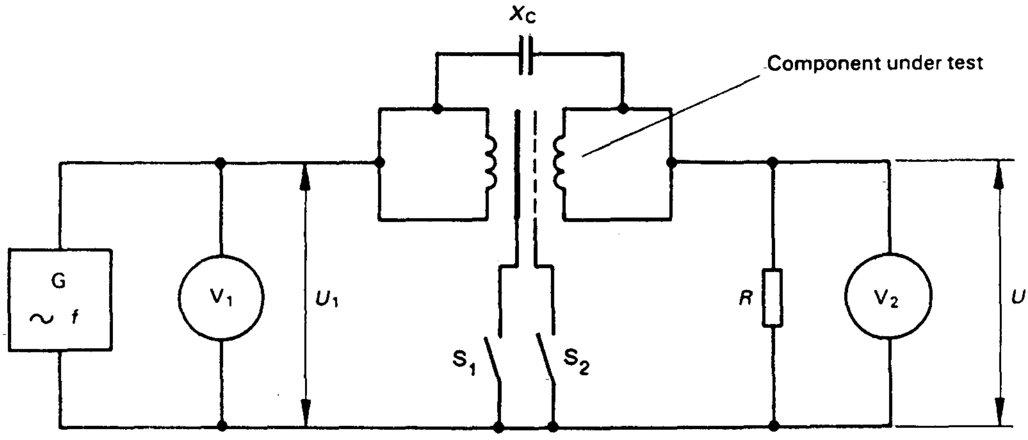


Figure 10 – Circuit for determining interwinding capacitance

The resistance of R should be 100 to 1 000 times smaller than the value of X_c. The values of U_1 and U_2 are read from the voltmeters V_1 and V_2 respectively, and the interwinding capacitance is calculated from the formula:

$$C = \frac{1}{2\pi f R} \times \frac{U_2}{U_1}$$

where f is the frequency of the generator G.

NOTE – Where many components have to be measured, it may be convenient to use fixed values of f, R and U_1 such that U_2 can be read directly in capacitance units.

Switches S_1 and S_2 allow the core, shield or both to be connected to earth.

Information to be stated:

a) winding connections;

b) for Procedure 1, frequency.

4.4.6.3 *Inter-element capacitance*

Purpose: To determine the effective capacitance between two elements of a transformer (e.g. winding to shield and/or core).

Procedure: As for 4.4.6.2.

Information to be stated: As for 4.4.6.2.

4.4.7 *Transformation ratios*

4.4.7.1 *Voltage transformation ratio*

Purpose: To verify that the voltage transformation ratio of two windings of a transformer is within specified limits.

Procedure 1: A supply of specified voltage and frequency shall be connected to the specified winding, all other windings being open-circuit. The output voltage of the appropriate winding shall be measured and the required ratio determined.

NOTES

1 The measuring instrument should be of sufficiently high impedance for the effect on the measured voltage to be negligible.

2 It is generally advisable to apply the test voltage to the highest impedance winding and measure the output of the low impedance winding at a frequency where the winding exhibits its highest *Q*-value but avoids self-resonance.

Information to be stated:

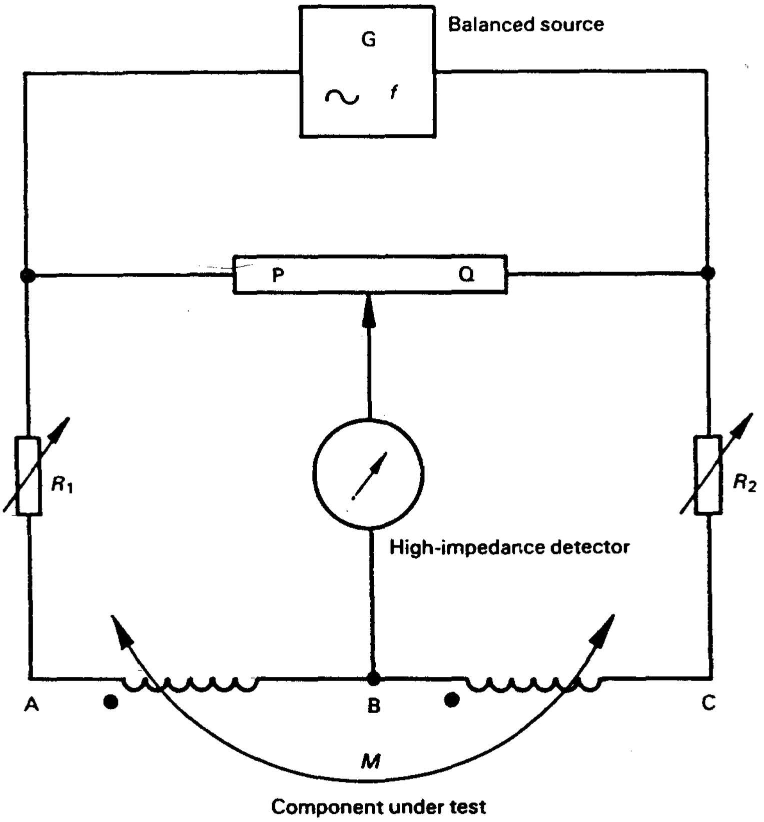
a) a.c. voltage;

b) measuring frequency;

c) windings to be connected and measured;

d) the voltage transformation ratio limits.

Procedure 2 (for single-phase components only): The two windings under test shall be incorporated in the bridge circuit as shown in figure 11. The two windings under test shall be connected so that the total inductance between terminals A and C is augmented by the effect of mutual inductance, M, between the windings. Resistors R_1 and R_2 are set to the values given in the detail specification and an initial balance is obtained by varying P/Q. A final bridge balance, as indicated by a minimum detector reading, shall then be obtained by adjustment of both R_1 (or R_2) and P/Q, and the voltage transformation ratio calculated as AB/BC = P/Q.



P and Q are non-reactive decade resistance units.

R_1 and R_2 are non-reactive variable resistors.

NOTE – Terminal letters are for reference only.

Figure 11 – Circuit for measurement of voltage transformation ratio

Information to be stated in the detail specification:

a) alternating voltage level;

b) measuring frequency;

c) initial values of R_1 and R_2;

d) terminations between which measurements are to be made;

e) voltage transformation ratio limits.

4.4.7.2 *Current transformation ratio*

Purpose: To determine the current transformation ratio between two windings of a current transformer.

Procedure: The current transformer, CT, is connected into the test circuit of figure 12. The tapping points on R_2 and M are adjusted for a null; the following equations are then valid:

$$k = \frac{i_1}{i_2} = \frac{R_2''}{R_1 \cos \beta}$$

$$\mathrm{tg}\,\beta = \frac{\omega M}{R_2''}$$

where

k is the current transformation ratio;

β is the phase angle between currents in the two windings;

R_2'' is the portion of R_2 in the detector loop ($R_2' + R_2'' = R_2$);

$\omega = 2\pi f$, where f is the measuring frequency.

NOTES

1 The polarities of the windings of the current transformer have to be as shown so that the voltages across R_1 and R_2'' are in series opposition with respect to the detector. The polarities of the windings of M should also be as shown to assure a balance is reached.

2 The value of R_2 should be chosen so that the secondary of CT is loaded at its rated burden. To a first approximation, the value of R_1 may be deduced from the chosen value of R_2, which in association with the rated burden largely determines i_2. Assuming that the specified value of k is correct, the value of i_1 can be calculated, and knowing the voltage of the test generator, the value of R_1 follows.

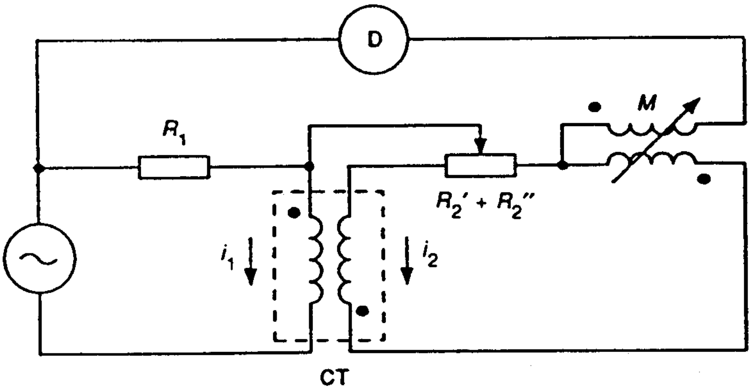
Information to be stated:

a) rated primary current;

b) rated burden;

c) measuring frequency;

d) current transformation ratio and tolerance.



CT is the current transformer under test
M is a variable mutual inductor
R_1 and R_2 are non-inductive resistors
D is a null detector
$R_2 = R_2' + R_2''$

Figure 12 – Circuit for the measurement of current transformation ratio

4.4.8 *Resonant frequency*

NOTE – In the following two tests, care should be taken to avoid inaccuracies caused by capacitance between test terminals or between the components and earth, especially if it is necessary to perform the test with the core connected to one of the test terminals.

4.4.8.1 *Inherent self-resonance*

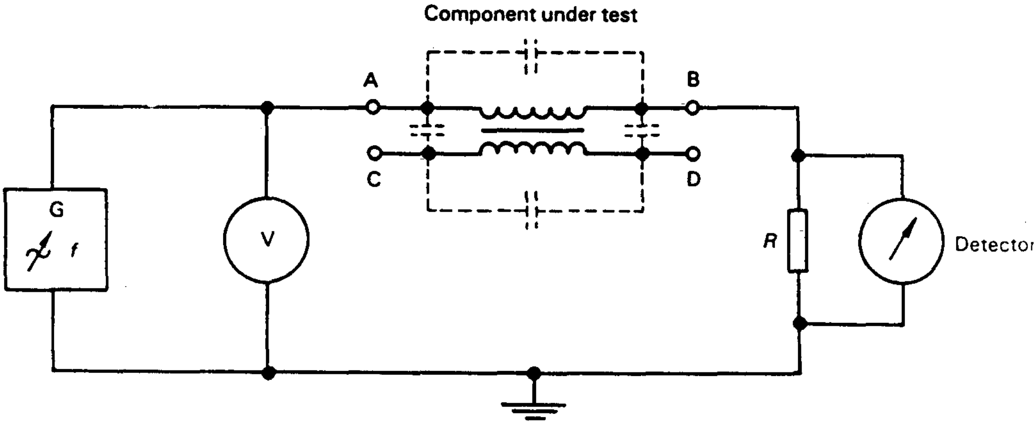
Purpose: To determine the frequency of parallel self-resonance of an inductive component.

Procedure: The component under test is connected into the test circuit of figure 13, whose elements satisfy the following requirements:

a) The signal source shall have a sufficiently low output impedance to supply the reactive current on each side of the resonant frequency.

b) The detector shall have a high impedance and a preferred minimum indication of 0,01 V.

c) The resistor *R* shall be non-reactive and shall have a value as low as practicable consistent with obtaining a suitable voltage level.



NOTE – Terminal letters are for reference only

Figure 13 – Circuit for determining parallel self-resonant frequency

Starting at the lowest frequency within the specified frequency range the frequency shall be increased and the voltmeter observed for a minimum reading. The frequency at which this minimum occurs is the self-resonant frequency.

Information to be stated:

a) a.c. voltage;

b) value of resistor *R*;

c) connections, including earthing of parts of the component and test circuit;

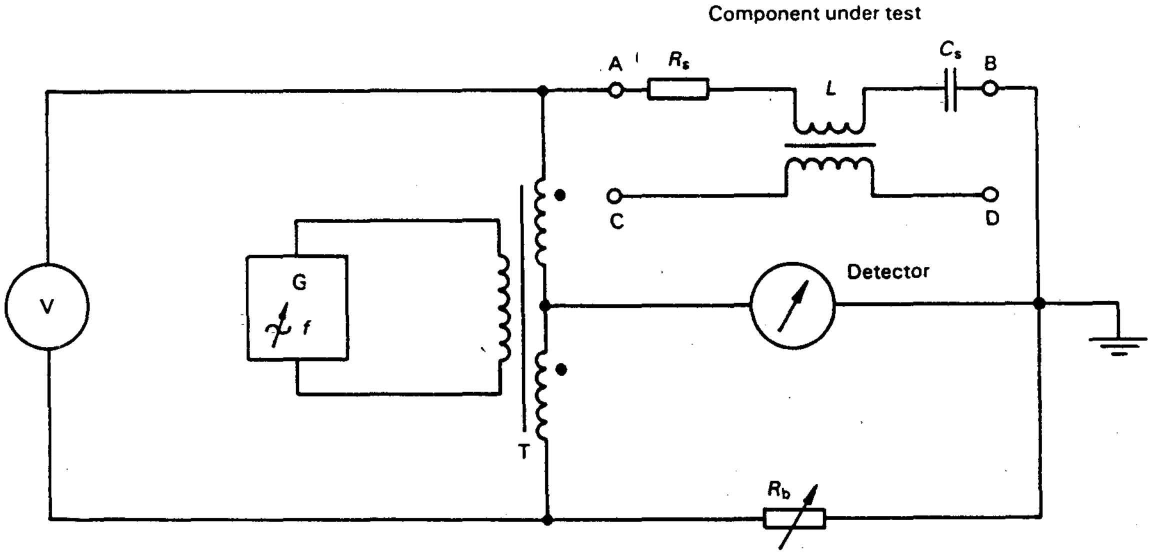
d) frequency range to be examined.

NOTE – Procedure 2 of 4.4.6.1 may be used as the basis of an alternative test method.

4.4.8.2 *Resonant assemblies*

Purpose: To determine the resonant frequency and, if required, the effective resistance of a component which normally includes the effects of added discrete components e.g. a resonating capacitor.

Procedure: With the component under test connected as shown in the basic circuit diagram given in figure 14, the frequency of the generator and the value of R_b shall be set approximately to the values specified in the detail specification. With the output of the generator maintained at the level specified in the detail specification, the generator frequency and the value of R_b shall be varied, each in turn, until minimum deflection is obtained on the detector. These values of f and R_b, which are noted, correspond to the required resonant frequency and the effective series resistance of the component under test.



G is a power oscillator, covering the required resonant frequency range, with an output adequate to energize the component to a level comparable with its normal application;

R_b is a non-reactive variable resistor of at least twice the value of the component's effective series resistance;

T is a screened transformer with an accurately balanced output winding suitable for use over the frequency range specified in the detail specification.

NOTES

1 The detector is a high-impedance meter of suitable sensitivity, suitable for the specified frequency range. This circuit element may incorporate a screened transformer.

2 Terminal letters are for reference only.

3 This circuit is also suitable for parallel combinations of L and C.

Figure 14 – Circuit for determining resonant frequency of resonant assemblies

Information to be stated in the detail specification:

a) the alternating voltage level(s);
b) the required resonant frequency limits (minimum and maximum);
c) the value of effective series resistance (maximum and/or minimum) if required;

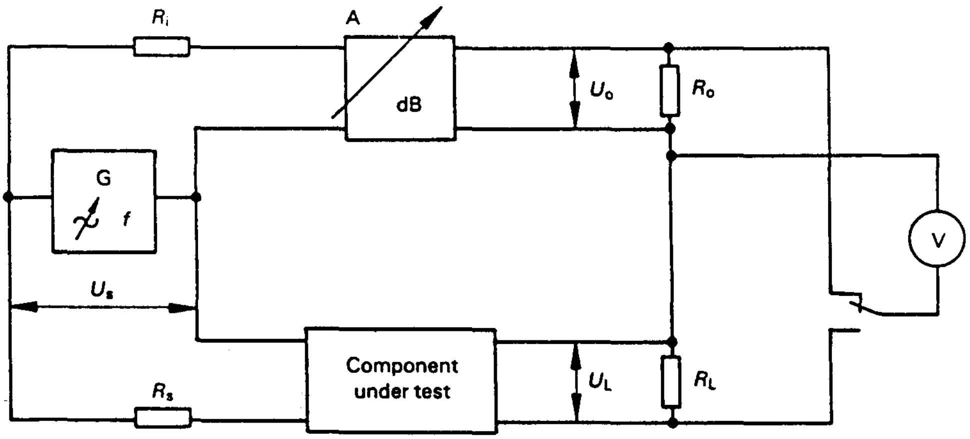
d) the loading details and connections with particular reference to the earthing of parts of the component(s).

4.4.9 *Signal transfer characteristics*

4.4.9.1 *Insertion loss*

Purpose: To determine the insertion loss of a transformer at a specified voltage and throughout a specified frequency range when the transformer is inserted between specified source and load impedances.

Procedure: The transformer shall be connected in the basic circuit of figure 15.



G	is a variable frequency generator covering the specified frequency range of the test.
A	is a precision variable attenuator having an input impedance R_i and output impedance R_o.
V	is a frequency selective, high-impedance voltmeter.
R_i	is a resistor of value equal to input impedance of the attenuator.
R_o	is a resistor of value equal to output impedance of the attenuator.
R_L	is a resistor of value equal to the specified load impedance of the transformer.
R_s	is a resistor of value equal to the specified source impedance of the transformer.
U_L	is the voltage across load.
U_s	is the voltage across source.
U_o	is the voltage across R_o.

NOTE – This arrangement applies only if $U_L \le U_s/2$ and $R_L \le R_s$.

Figure 15 – Circuit for determination of insertion loss

At each specified frequency U_L shall be measured and the attenuator adjusted to make U_o equal to U_L.

For a transformer ratio of 1:1 the insertion loss is equal to the attenuator reading.

If the ratio is not 1:1 the attenuator reading a_r shall be noted and the insertion loss a_i in decibels calculated from the expression:

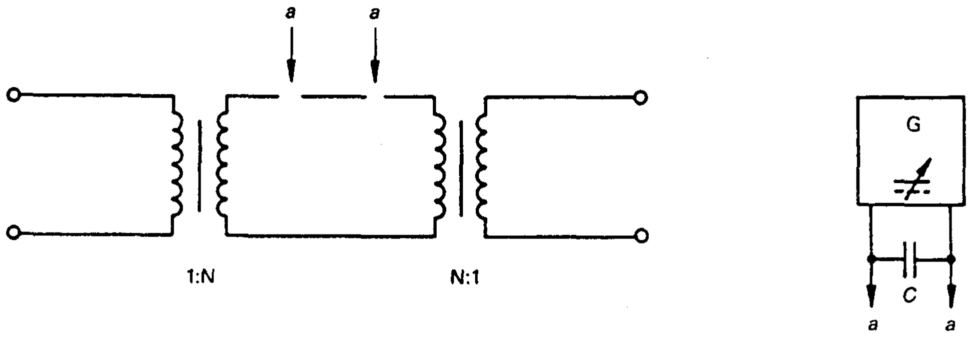
$$a_i = a_r - 10 \log (R_s/R_L)$$

This gives the correct insertion loss when any reactive part of the source and load impedances is defined as part of the transformer. If this is not so then the insertion loss between impedances Z_s (source impedance) and Z_L (load impedance) is given by:

$$a_i = 20 \log \left(\frac{U_s}{U_L} \left| \frac{Z_L}{Z_s + Z_L} \right| \right)$$

NOTE – In general, Z_s and Z_L are complex quantities.

When the transformer has a ratio significantly different from 1:1, more reliable measurements can be made by using two identical specimens in the manner shown in figure 16 to form the "component under test" of figure 15. This arrangement also facilitates making measurements when polarizing currents are required, as indicated by the inset to figure 16.



NOTE – C requires to be of negligible reactance at the test frequency.

Figure 16 – Use of two identical transformers when transformation ratio is not unity and/or a d.c. bias is required

In this case, the value of the insertion loss for each transformer shall be taken to be half the attenuator reading.

Information to be stated:

a) winding connections;

b) source impedance;

c) load impedance;

d) source voltage;

e) measuring frequency range;

f) polarizing current (if any).

NOTE – Unwanted couplings between input and output should be kept to a minimum by appropriate shielding and earthing.

4.4.9.2 *Return loss*

Purpose: To determine the degree of impedance mismatch, in terms of return loss, presented by a particular transformer winding when all other windings are terminated with their appropriate load impedances.

Return loss a_{rl} as a measure of mismatch between a source and a load is given in decibels by the expression:

$$a_{rl} = 10 \log (W_a/W_r)$$

where

W_a is the maximum available power in the load;

W_r is the reflected power.

Thus, as illustrated in figure 17, for a generator of output impedance R_G and open-circuit voltage U_o connected to a load R_L, the maximum available power condition occurs when $R_L = R_G$ and so under these circumstances

$$W_a = U_o^2 / 4R_G$$

When R_L has some other value, the difference between the actual power developed and the maximum possible in the load, that is the reflected power, is given by:

$$W_r = \frac{U_o^2}{4R_G} \left(\frac{R_L - R_G}{R_L + R_G} \right)^2$$

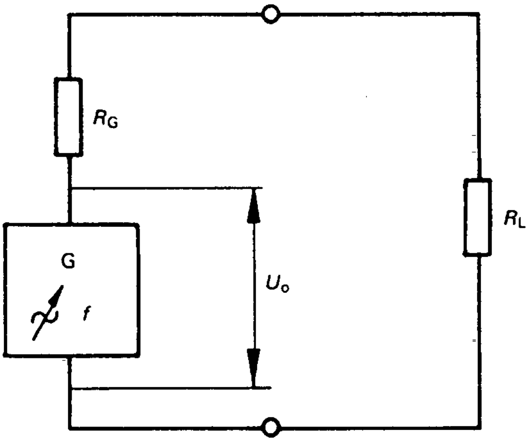


Figure 17 – Illustration of return loss

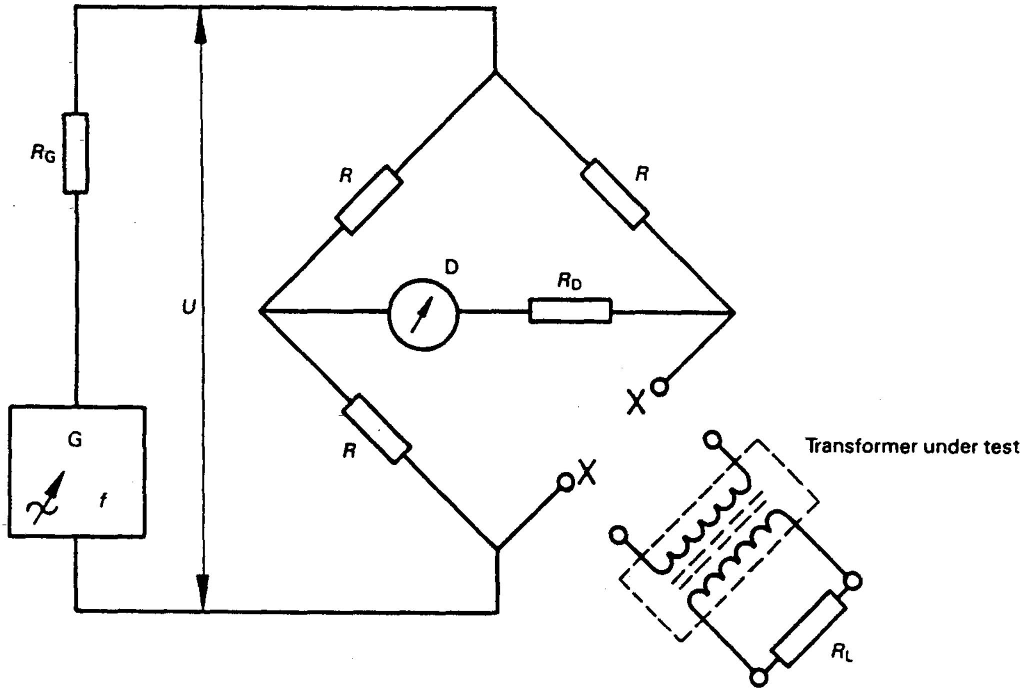
Hence the value of the return loss a_{rl} in decibels is given by:

$$a_{rl} = 20 \log \frac{R_L + R_G}{|R_L - R_G|}$$

Procedure: The basic bridge measurement circuit shown in figure 18 is set up with its elements equal to R_G and the source voltage U and source frequency f are set to the specified values. The initial bridge circuit loss registered on the calibrated decibelmeter D when the terminals X are either short-circuited or open-circuited is recorded. Let this loss be a_1. The terminated transformer under test is then connected to the terminals X and the loss indicated by D again recorded. Let this loss be a_2.

The return loss of the transformer a_{rl} in decibels is then given by the expression:

$$a_{rl} = a_2 - a_1$$



Resistors R are frequency independent and matched, relative to each other, to within ±0,1 %.
$R = R_G = R_D$ (= typically 600 Ω).
D is a decibel-meter, readily available for standard reference impedances such as 600 Ω.

Figure 18 – Basic return loss test circuit

NOTES

1 The initial bridge circuit loss a_1 should be close to 12 dB; the measured value is subject to the accuracy of the bridge circuit elements, particularly the source and calibrated decibel-meter impedances.

2 Suitable commercial measuring instruments incorporating the necessary network to provide a direct measurement of return loss are in common use and may be used.

Information to be stated:

- a) impedance against which the return loss is to be measured, R;
- b) winding connections;
- c) load resistance R_L or impedance Z_L;
- d) source voltage(s);
- e) measurement frequencies;
- f) d.c. current in output winding, if required.

4.4.10 *Frequency response*

Purpose: To determine the frequency response of a component when it is connected between specified source and load impedances.

Procedure: The component together with its specified source and load impedances shall be connected into a transmission measuring set, the basic circuit of which is the same as that used for the insertion loss measurement of 4.4.9.1 (see figure 15). If specified, other windings shall be loaded and polarizing d.c. applied. At the specified reference frequency, f_o, the attenuator shall be adjusted until U_o is equal to U_L as indicated by the frequency selective voltmeter. The attenuator reading shall be noted. The change in attenuator reading required to make U_o equal to U_L at any other frequency gives the relative gain or loss of the component at that frequency compared to the reference frequency. A plot of this gain (loss) against frequency constitutes a frequency response curve.

NOTE – Precautions such as screening, earthing and suppression of feedback by the use of co-axial chokes may be required, and corrections may be necessary to ensure that the response calculated from the reading of the calibrated attenuator gives the same result as determined from the following formula:

$$20 \log (U_f / U_{fo})$$

where

U_f is the output voltage at frequency f and

U_{fo} is the output voltage at the reference frequency f_o.

Information to be stated:

- a) component connections;
- b) source impedance(s);
- c) load impedance(s);
- d) source voltage;
- e) reference frequency f_o;
- f) frequency band or test frequencies;
- g) polarizing current, if any.

4.4.11 *Pulse characteristics*

Purpose: To verify that, with a specified pulse applied to the input winding of a transformer, the correct output waveform is obtained when the transformer is connected to the circuit for which it was designed.

Procedure: The specified input pulse shall be applied to the input winding with the output windings connected to the specified loads. The pulse obtained in the specified load shall be displayed on an oscilloscope having a calibrated time base and voltage deflection. The characteristics of the oscilloscope and its associated circuits shall be such that the pulse being displayed is not degraded because of excessive capacitance, insufficient bandwidth, etc.

The following measurements shall be made as required by the relevant specification:

a) peak pulse amplitude, U_m;
b) pulse duration, t_d;
c) pulse rise time, t_r;
d) pulse fall time, t_f;
e) pulse droop;
f) overshoot;
g) backswing;
h) return backswing;
i) recovery time.

Information to be stated:

a) input peak pulse amplitude, duration, rise time, fall time, droop and repetition frequency;
b) load impedance(s);
c) output characteristics to be measured;
d) ambient temperature.

4.4.12 *Voltage-time product rating*

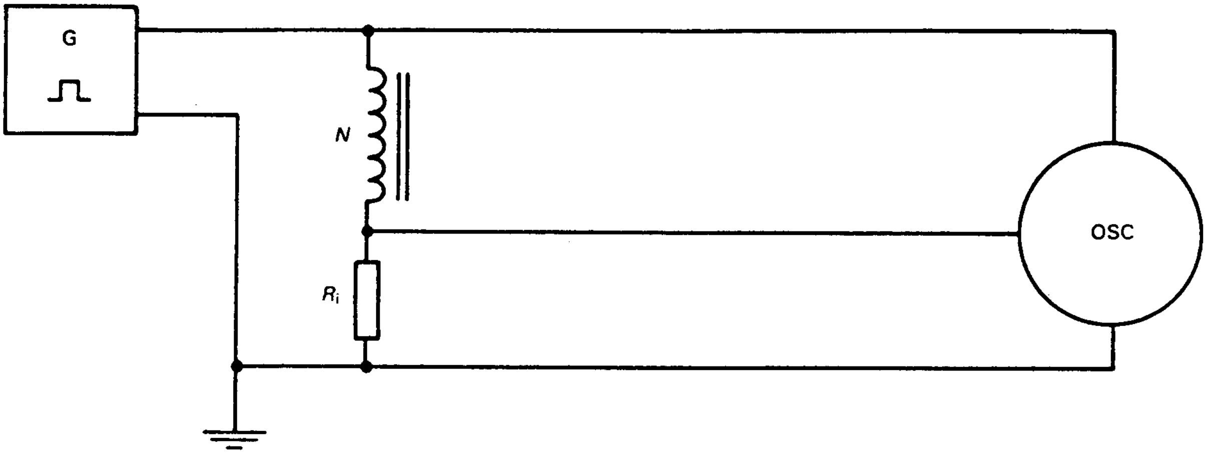
Purpose: To verify that the voltage-time product rating of a component (see 3.7) is within a stated limit.

NOTE – For applications involving bi-directional pulses, such as switched-mode power supplies, the voltage-time product will not be the same as for uni-directional pulses.

Procedure: When the specified test temperature differs from ambient, the component shall be heated in an oven until thermal equilibrium is obtained at the specified temperature.

If the transformer application involves a direct current in any of its windings the test shall be conducted with rated d.c. ampere-turns applied through a suitable impedance to prevent pulse-loading effects.

A rectangular voltage pulse of peak amplitude U_m shall then be applied to the specified winding for a pulse duration t_d and the corresponding magnetizing current monitored. An example of a suitable test circuit is shown in figure 19. (See also clause 16 and appendix M of IEC 367-1.)



R_i is a precision non-reactive resistor causing a voltage drop not exceeding 1 % of U_m.

Figure 19 – Circuit for verifying voltage-time product rating: measurement without bias and with single pulses

Requirement: The magnetizing current shall not exceed a specified percentage of the extrapolated linear portion of the current waveform at time t_d, that is, the non-linearity of the magnetizing current shall not exceed a specified value (see figure 20).

Information to be stated:

a) test temperature;

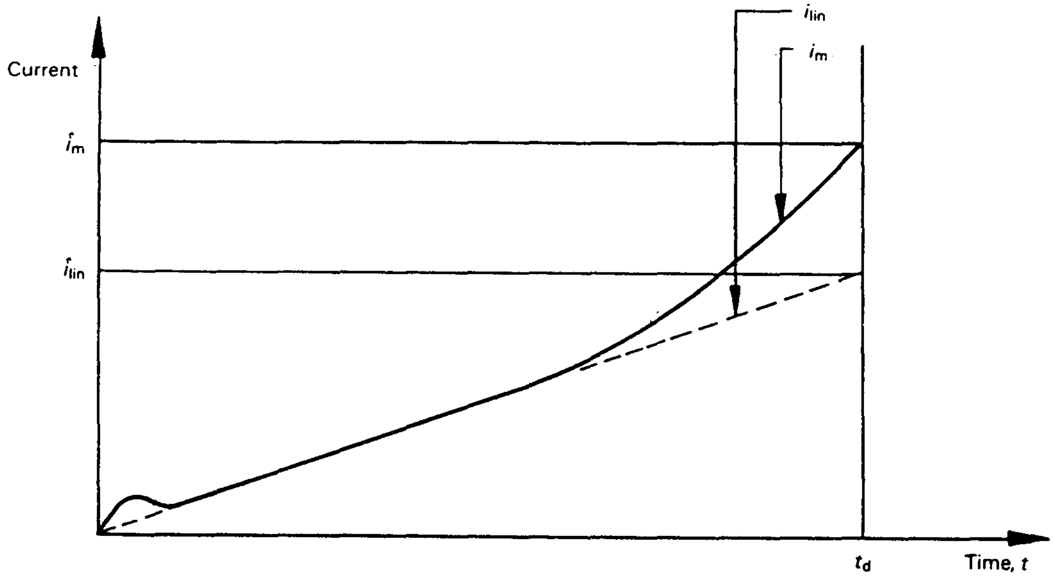
b) pulse amplitude, U_m (volts)*;

c) pulse duration, t_d (s)*;

d) if required, the value of superimposed d.c., its polarity and the terminations between which the d.c. is to flow;

e) maximum permissible non-linearity of magnetizing current.

According to the stated voltage-time product rating for the component.



$$\text{Non-linearity} = \frac{i_m}{i_{lin}} \times 100; \quad \text{maximum non-linearity} = \frac{\hat{i}_m}{\hat{i}_{lin}} \times 100$$

Figure 20 – Non-linearity of magnetizing current

NOTE – Several pulses might be necessary to obtain the required magnetic state of the transformer. Self-heating of core and winding should be avoided.

4.4.13 *Total harmonic distortion*

Purpose: To verify that the harmonic distortion produced by the component when associated with its specified source and load impedances does not exceed the specified limits.

Procedure: A voltage at the specified frequency shall be applied such that the specified output is achieved. The total harmonic content of the supply shall be at least ten times less than the output limit specified. When specified the appropriate direct current shall also be passed through the appropriate winding during the test. The total harmonic distortion shall then be determined by the use of either:

a) harmonic distortion measuring equipment giving a direct reading of total harmonic distortion, or

b) by the measurement of all significant harmonic voltages up to and including the seventh followed by the computation of total harmonic distortion from the following expression:

$$\left(\sum_{2}^{7} U_{f_n}^{2}\right)^{1/2} \times \frac{100}{U_{f_1}} \%$$

where

f_1 is the fundamental supply frequency;

f_n is the nth harmonic frequency of the supply;

U_{f_n} is the voltage at any particular harmonic frequency.

NOTE – The total harmonic distortion may also be expressed in decibels relative to the fundamental.

Information to be stated:

a) source impedance;
b) load impedance;
c) supply frequency;
d) output voltage at supply frequency;
e) polarizing current (if any).

4.4.14 *Voltage regulation*

Purpose: To establish the extent of voltage variation on specified winding(s) from the no-load condition to that at which the output winding(s) are simultaneously carrying the full load current.

Procedure: The specified input windings shall be energized at the rated voltage and frequency and the voltage across each winding shall be measured when all output windings are open-circuited. The specified loading shall be applied for the specified period or, in the absence of a statement, until thermal stability is achieved. The voltage across each winding shall be measured while the output windings are carrying their specified load currents. The percentage voltage regulation shall be calculated for each output winding using the following formula:

$$\frac{U_a - U_b}{U_a} \times 100$$

where

U_a is the voltage across the winding without load;

U_b is the voltage across the winding with load connected.

The voltage regulation shall be within the specified limits during and at the end of the test.

Information to be stated:

a) input supply condition;
b) output winding(s) load conditions;

c) duration of test;

d) details of duty cycle if other than continuous;

e) atmospheric conditions if other than standard;

f) details of mounting if other than on a thermally non-conducting surface;

g) voltage regulation limits during and at the end of the test.

4.4.15 *Temperature rise*

NOTE – The following tests are intended for proving the performance of series production components. A thermal probe (see 4.4.16) may be used, if required, as an alternative method for development items.

4.4.15.1 *Method utilizing the change in d.c. resistance of a winding*

Purpose: To determine the mean temperature rise of a component when it is subjected to a continuous duty cycle in a specified environment.

Procedure: The component under test shall be energized and loaded as specified in the detail specification. The d.c. resistance of the specified winding(s) shall be determined as in 4.4.1.1.

When thermal stability is achieved – i.e. when any change in input power does not exceed 2 % during a continuous period of 15 min, the power supply and load shall be disconnected and the d.c. resistance remeasured as in 4.4.1.1 with minimum delay. Minimum delay is necessary to ensure that the resistance measurement represents as closely as possible the highest temperature reached by the component during its operation under load. If required a cooling curve shall be developed and extrapolated back to establish the resistance R_2 at the instant of disconnection.

The temperature rise of the winding(s) shall be calculated using the following formula:

$$\theta_r = \frac{R_2}{R_1} (\theta_s + k) - (\theta_f + k)$$

where

θ_s is the ambient temperature at start of test (in °C);

θ_f is the ambient temperature at end of test (in °C);

θ_r is the winding temperature rise (in °C);

R_1 is the winding resistance immediately before energization (in Ω);

R_2 is the winding resistance immediately after disconnection of the energizing source (in Ω);

k is related to the thermal coefficient of resistivity: the value for copper shall be taken as 234,5 and for aluminium as 228,1 for the purpose of this standard .

Information to be stated:

a) information required by a) and b) of 4.4.1.1;

b) for conductor materials other than copper or aluminium the appropriate value of the constant k;

c) mounting details;

d) environment;

e) input supply conditions as appropriate:

   1) voltage and frequency,

   2) pulse duration and repetition frequency,

   3) polarizing current, ripple voltage and frequency;

f) output load(s).

NOTE – In some cases, adequate specification of loading may necessitate more detailed information, such as circuit diagrams and associated component values.

4.4.15.2 *Method using an additional series-opposing bifilar winding*

Purpose:

a) to measure temperature rise without interruption of power;

b) to measure rate of temperature rise.

Procedure: A bifilar winding is wound on or applied to the component with its two parts connected in series - opposition. The d.c. resistance of this winding shall be measured as in 4.4.1.1 and the temperature rise determined as in 4.4.15.1.

NOTES

1 This method may be used when there is an accessible free core or winding surface on which a suitable bifilar winding can be placed.

2 The application of thermal insulation to the bifilar winding may enable an estimate of internal component temperatures to be obtained.

3 This method may be adapted to the evaluation of prototypes by installing the bifilar winding between the functional windings of the component.

4 Where the observed resistance varies, according to whether the component under test is energized or not, the reading corresponding to absence of power should be used. The difference between the two conditions is attributable to eddy current effects.

Information to be stated:

a) details of additional bifilar winding, including position;

b) details of thermal insulation if required;

c) other information as in 4.4.15.1.

4.4.16 *Surface temperature*

Purpose: To determine the surface temperature of a transformer or inductor subjected to a continuous load within an environment specified in the detail specification.

Procedure: The conditions of test and procedures of 4.4.15.1 of this standard shall be applied until thermal equilibrium is achieved; i.e. until any change in input power does not exceed 2 % during a continuous period of 15 min.

The surface temperature shall then be measured with a thermal probe of low thermal conductivity and mass at a specified point on the component surface.

The surface temperature shall be recorded.

NOTES

1 The maximum surface temperature may be determined by scanning the component surface.

2 Measured values may be affected by:

- a) the thermal resistance between probe and component surface;
- b) electromagnetic fields, to which some probes are sensitive.

WARNING – Electrical shock hazard. Precautions must be taken physically and electrically to isolate the operator of the thermal probe from live or conducting parts of the component under test.

Information to be stated:

- a) information required by items c), d), e) and f) of 4.4.15.1;
- b) maximum surface temperature;
- c) specific points of measurement required by the customer.

4.4.17 *Phase test (polarity)*

Purpose: To establish that the windings are of the correct phase relative to one another.

Procedure 1: The windings whose relative phases are to be examined are connected in series. A supply of suitable voltage and frequency is connected to one of the test windings, and voltage measurements are made across the individual windings and their series assembly.

The addition of the voltages across the individual windings is compared with the voltage across the combined series winding.

For windings properly assembled with the phases (polarities) shown in figure 21, the following relationship is true:

$$U_3 = U_1 + U_2$$

For windings with opposite polarity:

$$U_3 = | U_1 - U_2 |$$

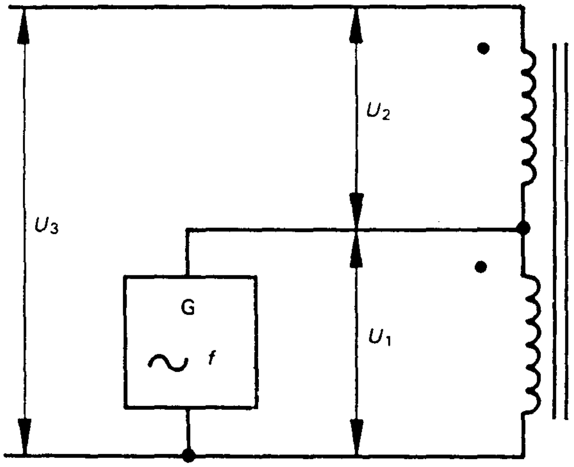


Figure 21 – Phase (polarity) test using voltage measurement

Information to be stated:

a) terminations to be connected together;

b) terminations between which the phase is to be determined.

Procedure 2: Using the bridge circuit and associated procedures given in Procedure 2 of 4.4.7.1, verify the relative phase of the windings to be tested.

NOTES

1 Incorrect polarity of AB relative to BC will result either in a balance at a value of P:Q different from that specified or failure to achieve a balance (see figure 11).

2 This procedure may not be feasible with some polyphase components.

Information to be stated:

a) winding connections giving the correct polarity of winding AB relative to winding BC;

b) the voltage transformation ratio limits;

c) test frequency and voltage;

d) if required, the approximate values of R_1 and R_2.

Procedure 3: The windings whose relative phases are to be examined are connected in series, as specified, and the inductance of the assembly is measured on a suitable bridge (see 4.4.4.1).

The result of this measurement is compared with the value calculated from the inductances of the individual windings as determined on the same bridge.

Thus, for the simplest case of two windings having inductance L_1 and L_2, the series connected windings will have a total measured inductance of:

$$L_1 + L_2 \pm 2k\sqrt{L_1 \; L_2}$$

where k is the coefficient of coupling, and the positive sign is associated with the series-aiding connection of the windings.

Reversal of the connection to one winding will thus produce a variation of $4k\sqrt{L_1 \; L_2}$.

NOTE – This method may not be suitable if the individual winding inductances are widely different, or if the coefficient of coupling between the test windings is small.

Information to be stated:

a) *terminations to be connected together;*

b) terminations between which the phase is to be determined;

c) test frequency and voltage.

Procedure 4: One end of each winding shall be connected to the common terminal of a two-channel oscilloscope. A supply of suitable voltage and frequency shall be connected to the Y1 input of the oscilloscope and to the free end of one winding. Each other free end or tap shall be connected in turn to the Y2 input terminal and the waveforms examined to establish their phase relationships.

Information to be stated:

a) terminations to be connected together;

b) terminations between which the phase is to be determined.

4.4.18 *Screens*

NOTE – Sometimes the word "shield" is used as an alternative, in English texts.

4.4.18.1 *Capacitance test for screens*

Purpose: To verify the electrostatic (shielding) effectiveness of each screen.

Procedure: On each side of the screen the windings shall be short-circuited and connected together. If the screen is isolated it shall be connected to the core (or case if the core is not accessible) for the test unless otherwise specified.

Measurement of the direct capacitance from the windings on one side of the screen to those on the other shall be made by Procedure 2 of 4.4.6.2. Care shall be taken to avoid the effect of extraneous parasitic capacitance. The results shall be compared with those obtained with the screen disconnected.

Information to be stated:

a) winding connections;

b) screen connection if other than to the core or case;

c) ratio of the capacitances: screen connected, to screen disconnected.

4.4.18.2 *Safety screens*

NOTE – Sometimes the term "isolating screen" is used as an alternative to "safety screen".

Purpose: To verify the existence and construction of any safety screens.

Procedure: The component shall be visually inspected by disassembly to verify the existence of any safety screens and the quality of their construction, taking into account the material and thickness of the screen, its width in relation to the width of the winding and its relative positioning, the cross-sectional area of the wire joining the screen to the external terminal and the quality of its joint to the screen.

If required, this destructive test shall be substituted by visual inspection during the manufacturing stage, when screen and joints are visible.

A final check on completed components shall be made by means of capacitance and dielectric insulation tests (see 4.4.18.1 and 4.4.2).

Information to be stated:

a) whether test is to be carried out during manufacture or as a destructive test on a completed component;

b) screen material and thickness;

c) screen width;

d) cross-sectional area and material of wire connecting screen to its connecting terminal and method of connection;

e) terminal size and material.

4.4.19 *Noise*

4.4.19.1 *Acoustic noise*

Purpose: To determine the level of audible noise radiated to the environment by the component under specified conditions.

Procedure: Whenever possible the component to be tested shall be fastened (bolted, soldered, etc.) to the chassis or other mechanical structure on which it is to be permanently mounted during its operation. The component shall then be placed in a chamber free from any noise-reflecting surface except that of the chassis or mechanical structure that contains the mounted component. The level of the background noise (see 3.8) in the chamber shall be at least 4 dB(A) and preferably 9 dB(A) lower than the combined sound level of the component and the chamber background noise.

The background noise level shall be taken to be the average of the measurements taken immediately before and immediately after the component is tested at each of the locations specified.

If the background level is such that the difference in dB(A), between the mean combined sound level of the component plus the background and the mean background level is less than 10 dB(A), but not less than 4 dB(A), the corrections shown in the table below shall be applied. If this difference is less than 4 dB(A) the test shall not be accepted and efforts shall be made to lower the background noise level.

Sound-level corrections for audible noise tests

Difference in dB(A) between the mean combined sound level of the component plus the background and the mean background alone	Corrections in dB(A) to be subtracted from the mean combined sound level of the component plus the background to obtain sound level of the component
4	2,2
5	1,7
6	1,3
7	1,0
8	0,8
9	0,6
10	0,4
Over 10	0,0

The component shall be on no-load and shall be energized at rated frequency and rated voltage from a source of specified waveform connected to the specified terminations.

Sound levels shall be measured with an instrument that is in accordance with IEC 651, of type 1F.L (F - fast response indication; L - for laboratory use) and having a minimum reading not less than 40 dB(A). The frequency weighting characteristic A of the instrument shall be used.

Measurements shall be taken with the probe of the sound-level meter located at the specified distance which shall be not greater than 0,3 m from the surface of which the acoustic radiation is to be measured. The readings shall be taken at the centre of each of the four vertical plane surfaces and at the centre of the top horizontal surface bordering the component. The surfaces are assumed to be those from which sound is radiated and are determined by faces of the hexahedron describing the component contour, excluding bushings, turrets, lugs, etc.

The average sound level of component plus background or background alone is calculated from the arithmetic mean of the sound levels measured as above. The average sound level of the component is calculated taking the corrected sound-level values for each measuring position.

Information to be stated:

a) mounting details;

b) distance of sound-level meter from test surfaces;

c) winding connections;

d) voltage and frequency of component energization.

NOTE – In the cases of components that are constructed with auxiliary elements such as forced-air or oil coolers – e.g., for components of large dimensions and/or possessing distinctly directional acoustic radiation, the acoustic noise measurement should be performed according to IEC 551.

4.4.19.2 *Electromagnetic noise*

Electromagnetic noise concerns the emission or the reception of unwanted signals having associated electric and magnetic fields, throughout the frequency spectrum used for power transmission and communications. Since electromagnetic noise concerns complete equipment rather than individual components, no test methods are included in this standard.

Specifications for the limits of emitted noise and for immunity of equipment in the presence of noise are dealt with under the general heading of electromagnetic compatibility (EMC)*.

4.4.20 *Corona test*

The Corona test shall be made in accordance with IEC 270.

NOTE – IEC 44-4 covers routine tests for this specific application.

4.4.21 *Magnetic fields*

4.4.21.1 *Magnetic shielding*

Purpose: To determine the influence of an external magnetic field on a component.

Procedure: The component shall be placed in a uniform alternating magnetic field of the specified strength and frequency and the voltage across the specified winding shall be measured with a voltage detector having an input impedance of not less than 1 MΩ. The component shall be rotated and the maximum voltage recorded.

NOTE – A uniform field is produced by a Helmholtz structure (see figure 22) with a coil diameter at least twice the maximum dimension of the component. With the coils connected in series-aiding, a simplified formula for the field strength H in A/m is:

$$H = \frac{0{,}716\,Ni}{r}$$

where

N is the number of turns of each coil;

r is the coil radius (i.e. coil axial spacing) (in metres);

i is the peak current (in amperes).

Dimensions of Helmholtz structure for components of up to 275 mm maximum dimension are given in figure 22, each coil consisting of 1 500 turns of 0,2 mm diameter wire.

Committees involved in the publication of EMC documents include: TC 65: Industrial-process measurement and control; TC 77: Electromagnetic compatibility between electrical equipment including networks; and CISPR: International Special Committee on Radio Interference. (Details of the publications are given in the IEC Yearbook.)

Information to be stated:

a) magnetic field strength in amperes/metre;
b) frequency of the alternating magnetic field;
c) winding whose output voltage is to be measured;
d) axes of rotation.

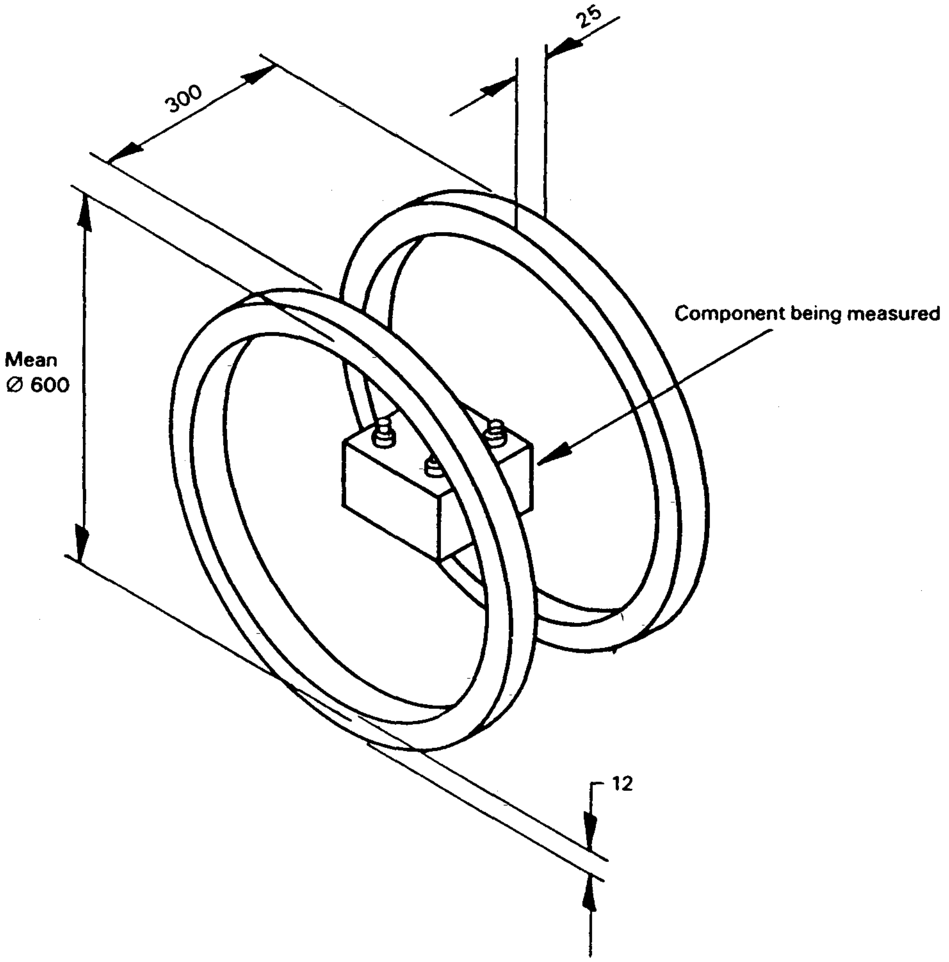


Figure 22 – Helmholtz structure

4.4.21.2 *Magnetic influence (compass safe distance)*

Purpose: To determine the minimum distance from a compass at which a transformer or similar wound component may be placed to limit the deviation to a stated value under all conditions of operation (see 3.9).

Conditions of measurement: Measurements shall be made in a uniform magnetic field. If the horizontal component of this field has a value outside the limits 13 A/m to 16 A/m then the compass safe distance, D_{cs} (in metres), shall be calculated from the following expression:

$$D_{cs} = 14{,}4\ D_m/H$$

where

D_m is the measured distance (in metres);

H is the actual field strength (in amperes/metre).

Procedure: The test area shall be marked out with magnetic N-S and E-W lines and a suitable magnetometer placed at the intersection of these lines. The magnetometer (which may be a compass) shall be capable of being read to an accuracy of one-fifth of a degree and shall possess a corresponding sensitivity.

The component under test shall be placed on the E-W line at a distance from the magnetometer that gives a deviation of approximately 2°.

Experiments shall be made to determine the combination of attitude and degree of energization that gives the maximum deviation of the magnetometer. This combination shall be maintained while the component is moved outwards along the E-W line until the magnetometer deviation is approximately 0,5°. From readings taken at intervals during this movement a curve shall be plotted showing magnetometer deviation against distance.

As a check on experimental error a curve shall also be plotted to correspond to an inward movement of the component. The two curves, which should be substantially coincidental, shall be used to establish accurately the distance at which a 1° deviation of the magnetometer is experienced. This distance shall be recorded as the compass safe distance for the component.

The compass safe distance of equipment that produces a significant directional magnetic effect shall be measured if so required along other axes defined by the relevant specification and its value declared.

Information to be stated:

- the connections to be made to the component under test.

4.4.21.3 *Magnetic radiation*

Purpose: To determine the extent of the magnetic influence of a component on its environment.

Procedure: The component shall be located at the centre of a non-metallic (insulating) cube fixture that will permit the centre of a search coil to be moved freely over the surfaces of the whole area of the external faces of the cube.

Cube dimensions, together with corresponding search coil data, shall be as follows:

Operating frequency band	Cube fixture dimension mm	Search coil data
10 Hz to 150 Hz	300	1 500 turns of enamelled copper wire, 0,315 mm diameter, wound into a coil, 285 mm internal diameter, 75 mm long
150 Hz to 30 kHz	150	Single-turn loop of 1 mm wire, 150 mm diameter
30 kHz to 5 MHz	75	Single-turn loop of 1 mm wire, 75 mm diameter
Above 5 MHz	37	Single-turn loop of 0,71 mm wire, 37 mm diameter

With the component energized and loaded as specified, the external faces of the cubic fixture shall be scanned and the maximum peak output voltage indicated by means of a high impedance detector connected across the search coil shall be noted. This value shall not exceed the limit specified in the relevant specification.

Information to be stated:

a) alternating voltage level(s);
b) measuring frequency(ies);
c) load impedance(s);
d) if required, the limit values of the peak voltage across the search coil.

4.4.22 *Inrush current*

Since it is considered that inrush current is primarily significant for complete equipment rather than individual components, no test methods are included in this standard.

4.5 *Environmental test procedures*

4.5.1 *General*

4.5.1.1 *Capability approval*

The test conditions together with the initial, final and intermediate measurements to be made shall be as prescribed by the relevant schedule in a future IEC standard.

4.5.1.2 *Quality conformance inspection*

Where environmental tests are prescribed by a detail specification, use can be made of the procedures (if applicable) listed below, which, with the exception of the tests for fire hazard, are taken from IEC 68-2.

NOTE – Users should ensure that they are in possession of the appropriate issued texts.

Alternatively the detail specification writer may choose the test conditions from the options given in the relevant part of IEC 68.

The severity of the test, and the initial, final and intermediate measurements to be made shall be given in the quality conformance schedule of the detail specification.

4.5.2 *Soldering*

IEC 68-2-20 Test T. The appropriate test method of test Ta, as specified in the detail specification, shall be used for the determination of the solderability of wire and tag terminations.

NOTES

1 For components intended exclusively for printed wiring applications, only method 1 of test Ta should be used.

2 Where the resistance of components to soldering heat is specified, method 1B of test Tb applies.

3 The relevance of IEC 68-2-58 Test Td should be noted for application to such devices.

4.5.3 *Robustness of terminations and integral mounting devices*

IEC 68-2-21 Test U. Tests Ua1, Ua2, Ub, Uc or Ud shall be used as specified in the detail specification according to the type of termination. As a result of the test there shall be no visible damage to the termination, fixing or sealing and connections to the terminations shall be satisfactory when tested in accordance with 4.4.1.2.

4.5.4 *Shock*

CEI 68-2-27 Test Ea and guidance.

4.5.5 *Bump*

CEI 68-2-29 Test Eb and guidance.

4.5.6 *Vibration (sinusoidal)*

CEI 68-2-6 Test Fc and guidance.

4.5.7 *Acceleration, steady state*

CEI 68-2-7 Test Ga and guidance.

4.5.8 *Rapid change of temperature (thermal shock in air)*

IEC 68-2-14 Test N. Test Na as specified.

4.5.9 *Sealing*

IEC 68-2-17 Test Q. Test Qc or Qd as specified.

4.5.10 *Climatic sequence*

The following test sequence shall be applied:

a) Dry heat, test Ba. The specimen shall be subjected to test Ba of IEC 68-2-2 at upper category temperature. Duration 16 h.

b) Interval 1. An interval not exceeding 72 h is permitted at this stage of the procedure; during the interval the specimen shall be kept at a temperature between 15 °C and 35 °C under normal laboratory conditions.

c) Damp heat (cyclic), test Db. Any specimen with a climatic category of –/–/10, –/–/21 or –/–/56 shall be subjected to test Db of IEC 68-2-30 at severity b) 55 °C for 1 cycle, variant 1 followed by a recovery period of between 1 h 30 to 2 h.

d) Cold, test Aa. Immediately after the damp heat cycle of c) the specimen shall be subjected to test Aa of IEC 68-2-1 for a period of 2 h at lower category temperature.

e) Interval 2. An interval not exceeding 72 h is permitted at this stage of the procedure; during the interval the specimen shall be kept between 15 °C and 35 °C under normal laboratory conditions.

f) Low air pressure, test M. If required (see note), any specimen with a climatic category 40/–/–, 55/–/– or 65/–/– shall be subjected to IEC 68-2-13 Test M at the prescribed degree of severity. The low-pressure conditioning shall be carried out between 15 °C and 35 °C for 1 h, unless otherwise specified in the detail specification.

g) Interval 3. An interval not exceeding 72 h is permitted at this stage of the procedure only if the low air-pressure test of f) has been carried out; during the interval the specimen shall be kept between 15 °C and 35 °C under normal laboratory conditions.

h) Damp heat (cyclic), test Db. Specimens of category –/–/10, –/–/21 and –/–/56 shall then be subjected to test Db of IEC 68-2-30 at severity b) 55 °C for 1 cycle, variant 1.

Where specified the specimen shall be removed from the chamber after the specified number of cycles, shaken to remove droplets of water and within 15 min shall be subjected to relevant electrical and mechanical tests.

i) Recovery. The specimen shall be allowed to recover for between 1 h 30 and 2 h under standard conditions for recovery.

NOTE – For capability approval the low air-pressure test is optional.

4.5.11 *Damp heat, steady state*

IEC 68-2-3 Test Ca.

4.5.12 *Dry heat*

IEC 68-2-2 Test B.

4.5.13 *Mould growth*

IEC 68-2-10 Test J and guidance.

4.5.14 *Salt mist, cyclic (sodium chloride solution)*

IEC 68-2-52 Test Kb.

NOTE - Where test Kb is specified and it is wished to use a salt solution which corresponds to a marine environment, the following composition is recommended:

sodium chloride NaCl	26,5 g
magnesium chloride $MgCl_2$	2,4 g
magnesium sulphate $MgSO_4$	3,3 g
calcium chloride $CaCl_2$	1,1 g
potassium chloride KCl	0,73 g
sodium bicarbonate $NaHCO_3$	0,20 g
sodium bromide NaBr	0,28 g
distilled water to make up 1 l	

(The above masses shall be accurate to within ±10 %; they refer to anhydrous salts of laboratory reagent grade.)

4.5.15 *Sulphur dioxide test for contacts and connections*

IEC 68-2-42 Test Kc.

4.5.16 *Fire hazard*

Test for fire hazard shall be selected from IEC 695.

NOTE – IEC 695-2-2 Needle-flame test is more appropriate for small components. The Bunsen-type flame test of IEC 695-2-4 is more appropriate for larger components.

4.5.17 *Immersion in cleaning solvents*

IEC 68-2-45 Test XA and guidance.

4.6 *Endurance test procedures*

4.6.1 *Short-term endurance (load run)*

Purpose: To assess the capability of the component to function satisfactorily during continuous operation or during duty cycles specified in the detail specification.

Procedure: The component shall be free-standing on a surface of low thermal conductivity, unless otherwise specified in the detail specification.

a) For transformers, separate loads shall be connected to each winding as specified in the detail specification. The value of these loads shall be such that the maximum rated power of each winding will be dissipated, unless otherwise specified in the detail specification.

An appropriate power supply shall be connected to the input winding and applied continuously for 6 h under standard atmospheric conditions, unless otherwise specified in the detail specification. During the load run, the load(s) shall be adjusted as necessary to ensure that the specified load conditions are maintained.

b) For inductors, the rated ripple voltage shall be applied, and the rated polarizing current passed continuously for 6 h under standard atmospheric conditions, unless otherwise specified in the detail specification. During the load run, the supply or supplies shall be adjusted as necessary to ensure that the rated conditions are maintained.

Information to be stated in the detail specification:

a) the input supply conditions as appropriate:
  - rated voltage and frequency;
  - rated pulse duration and repetition frequency;
  - rated polarizing direct current, ripple frequency and voltage;

b) the load conditions of the output winding(s);

c) the duration of test, if other than 6 h;

d) the details of the duty cycle, if other than continuous;

e) the atmospheric conditions for test, if other than standard;

f) the details of mounting, if other than free-standing on a surface of low thermal conductivity;

g) the requirements to be satisfied during and at the end of the test.

4.6.2 *Long-term endurance (life test)*

Purpose: To determine the capability of a component to withstand repetitive cycles of operation under the load conditions specified in the detail specification.

Procedure: The component shall be free-standing on a surface of low thermal conductivity, unless otherwise specified in the detail specification.

a) For transformers, separate loads shall be connected to each winding as specified in the detail specification. The value of these loads shall be such that the maximum rated power of each winding will be dissipated, unless otherwise specified in the detail specification.

b) For inductors, the rated ripple voltage shall be applied and the rated polarizing current shall be passed through the winding.

Components shall be subjected to a minimum of five endurance cycles per week to a total of 85 cycles. Each of the cycles shall consist of 24 h, during which time the components shall be energized at upper category temperature for 20 h continuously, and for the remaining 4 h the component shall be kept without excitation under standard atmospheric conditions

Information to be stated in the detail specification:

a) the input supply conditions as appropriate:
  - rated voltage and frequency;
  - the rated pulse duration and repetition frequency;
  - the rated polarizing direct current, ripple frequency and voltage;

b) the load conditions of the output winding(s);

c) the details of the duty cycle, if other than continuous;

d) the details of mounting, if other than free-standing, on a surface of low thermal conductivity;

e) the requirements to be satisfied during and at the end of the test.

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